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ALTERNATIVE WASTE MANAGEMENT TECHNIQUES FOR BEST PRACTICABLE WASTE TREATMENT.

U.S. ENVIRONMENTAL PROTECTION AGENCY
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This document is intended to provide information pursuant to Section 304(d)(2) of the Federal Water Pollution Control Act Amendments of 1972 (the Act) on practicable techniques by which publicly-owned treatment works can restore and maintain the integrity of the Nation's waters. The document identifies the currently known techniques, summarizes the technology, and includes an extensive bibliography.

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CHAPTER I. INTRODUCTION

This document is intended to provide information pursuant to Section 304(d)(2) of the Federal Water Pollution Control Act Amendments of 1972 (the Act) on practicable techniques by which publicly-owned treatment works can restore and maintain the integrity of the Nation's waters. The document identifies the currently known techniques, summarizes the technology, and includes an extensive bibliography (Appendix A).

A. Statutory Requirements

The Act (P. L. 92-500) refers to best practicable waste treatment technology (BPWTT), or to the manner in which it is to be determined, in three key sections.

Under Section 304(d)(2), which imposes the earliest deadline ("within nine months of the enactment of this title, and from time to time thereafter"), EPA is to publish:

> "Information on alternative waste treatment management techniques and systems available to implement Section 201 of this Act."

Section 201, the only section where the phrase "best practicable waste treatment technology" actually appears, declares that:

> "Waste treatment management plans and practices shall provide for the application of the best practicable waste treatment technology before any discharge into receiving waters, including reclaiming and recycling of water, and confined disposal of pollutants so they will not migrate to cause water or other environmental pollution and shall provide for consideration of advanced waste treatment technques."

To realize this purpose, Section 201(g)(2)(A) stipulates that:

> "The Administrator shall not make grants from funds authorized for any fiscal year beginning after June 30, 1974, . . . unless . . . alternative waste management techniques have been studied and evaluated and the works proposed for grant assistance will provide for the application of the best practicable waste treatment technology over the life of the works consistent with the purposes of this title."

Funds for FY 1975, the first year affected by the BPWTT requirement, became available January 1, 1974.

Under Section 301(b)(2)(B) the requirements which pertain to publicly-owned treatment works (POTW's) receiving Federal funds are generalized to all POTW's for 1983:

> **"In order to carry out the objective of this Act (to restore and maintain the chemical, physical, and biological integrity of the Nation's waters) there shall be achieved . . . not later than July 1, 1983, compliance by all publicly owned treatment works with the requirements set forth in Section 201(g)(2)(A)** of this Act."

In summary, the information developed under Section 304, which is first used for funding purposes under Section 201, is eventually used for enforcement purposes under Section 301. This is accomplished through National Pollutant Discharge Elimination System (NPDES) permits issued under Section 402, which allow the discharge of pollutants, provided the discharge meets all applicable requirements of the Act (in this case, of Section 301).

B. Legislative History

The earliest guidance on Sections 201, 301, or 304 is contained in the Senate Committee Report's comments on Section 201. There is a strong emphasis on land disposal, reflecting the original version of the legislation. It required land treatment as BPWTT except where a municipality could prove the superiority of another technique. In a different vein, the Committee also warned against reliance on conventional dry-weather waste treatment technology. The Committee noted that in many places water quality objectives will remain beyond reach until attention is given to the treatment of storm water runoff and combined sewer overflows.

The House Committee Report on Section 201 is in many respects a rejoinder to the Senate report. The House Committee warned against reliance on any one treatment technique as a panacea. Rather, it listed three standard alternative techniques for consideration: treatment and discharge to receiving water, treatment and reuse, and spray-irrigation or other land disposal methods. In its comments on Section 304, how-

ever, the House Committee did urge that the information EPA publishes on alternative waste management techniques emphasize land disposal. Finally, under Section 201, the House stressed that any determination of BPWTT should consider possible trade-offs between air, land, and water disposal of pollutants.

C. Synopsis

The information contained in this document will guide policy-owned treatment works in selecting waste treatment alternatives to restore and maintain the integrity of the Nation's waters.

Chapter II specifies the criteria to meet best practicable waste treatment for the broad categories of treatment and discharge into navigable waters, land application and utilization practices, and reuse of treated wastewater. Criteria less stringent than those established in Chapter II are not acceptable. Criteria which are more stringent must be justified or be pursuant to more stringent State and local law.

Chapters III, IV, and V develop the rationale behind the criteria as well as present information pertaining to acceptable alternative waste management techniques. These chapters are not intended to include all possible approaches that are or might become practicable. Therefore, techniques and technologies not discussed in this document can be employed to achieve the criteria in the most cost-effective manner.

CHAPTER II:
CRITERIA FOR BEST PRACTICABLE WASTE TREATMENT

Applicants for construction grant funds authorized by Section 201 of the Act must have evaluated alternative waste treatment management techniques and selected the technique which will provide for the application of best practicable waste treatment technology. Alternatives must be considered in three broad categories: treatment and discharge into navigable waters, land application and utilization practices, and reuse of treated wastewater. An alternative is "best practicable" if it is determined to be cost-effective in accordance with the procedures set forth in 40 CFR Part 35 (Appendix B to this document) and if it will meet the criteria set forth below.

(A) Alternatives Employing Treatment and Discharge into Navigable Waters

Publicly-owned treatment works employing treatment and discharge into navigable waters shall, as a minimum, achieve the degree of treatment attainable by the application of secondary treatment as defined in 40 CFR 133 (Appendix C). Requirements for additional treatment, or alternate management techniques, will depend on several factors, including availability of cost-effective technology, cost and the specific characteristics of the affected receiving water body.

(B) Alternatives Employing Land Application Techniques and Land Utilization Practices

Publicly-owned treatment works employing land application techniques and land utilization practices which result in a discharge to navigable waters shall meet the criteria for treatment and discharge under Paragraph (A) above.

The ground water resulting from the land application of wastewater, including the affected native groundwater, shall meet the following criteria:

Case I: The ground water can potentially be used for drinking water supply.

(1) The standards for chemical quality and pesticides specified in the EPA Manual for Evaluating Public Drinking Water Supplies (Appendix D) for drinking water supply sources should not be exceeded except as indicated below (See Note 1).

(2) If the existing concentration of a parameter exceeds the standards for chemical quality or pesticides, there should not be an increase in the concentration of that parameter due to land application of wastewater.

Case II: The ground water is used for drinking water supply.

(1) The criteria for Case I should be met.

(2) The bacteriological standards for drink-

ing water supply sources specified in the EPA Manual for Evaluating Drinking Water Supplies (Appendix D) should not be exceeded (See Note 1).

Case III: Uses other than drinking water supply.

(1) Ground water criteria should be established by the Regional Administrator based on the present or potential use of the ground water.

The Regional Administrator in conjunction with the appropriate State officials and the grantee shall determine on a site-by-site basis the areas in the vicinity of a specific land application site where the criteria in Case I, II, and III shall apply. Specifically determined shall be the monitoring requirements appropriate for the project site. This determination shall be made with the objective of protecting the ground water for use as a drinking water supply and/or other designated uses as appropriate and preventing irrevocable damage to ground water. Requirements shall include provisions for monitoring the effect on the native ground water.

(C) Alternatives Employing Reuse

The total quantity of any pollutant in the effluent from a reuse project which is directly attributable to the effluent from a publicly-owned treatment works shall not exceed that which would have been allowed under Paragraphs (A) and (B) above.

NOTE 1

Any chemical, pesticides, or bacteriological standards for drinking water supply sources hereafter issued by EPA shall automatically apply in lieu of the standards in the EPA Manual for Evaluating Public Drinking Water Supplies.

CHAPTER III:
WASTE MANAGEMENT TECHNIQUES INVOLVING LAND APPLICATION OR LAND UTILIZATION

Land application systems can be classified with respect to the ultimate disposition of the applied wastewater: (1) percolation of wastewater through the soil until it becomes part of the permanent aquifer and (2) collection of land applied wastewater either by means of underdrain systems or as a result of surface runoff. Percolation systems which result in permanent ground water must meet the ground water quality criteria established for such systems. Land application systems which collect the applied wastewater in underdrain systems and/or result in surface runoff must comply with the wastewater treatment and discharge criteria if the collected wastewater is discharged to navigable waters.

Three different cases can be identified for percolation of wastewater through the soil: (1) the receiving ground water has the potential for use as a drinking water supply; (2) the receiving ground water is used as a drinking water supply; and (3) the receiving ground water has other uses. Achieving best practicable technology for these cases requires meeting the applicable ground water criteria. The specific ground water criteria are determined on the basis of the level of ground water protection necessary.

Where the receiving ground water has the potential to be used as a drinking water supply, the bacteriological criteria for drinking water supplies (Appendix D) can be met by standard water treatment practice at a reasonable cost. However, because the water treatment technology available for the removal of chemical pollutants and pesticides is not widely practiced and is costly, the chemical and pesticide criteria (Appendix D) should apply when land application is considered.

In the case of receiving ground water which is already being used as a public or private water supply, protection of the ground water from pathogenic pollution is necessary in addition to meeting chemical and pesticides criteria. The bacteriological criteria in this case should be consistent with the level of treatment received by the ground water prior to public use. If, for example, a number of existing private wells use the ground water resulting from the land application system, the bacteriological standards for ground water usable without treatment shall apply.

When the ground water is not being used as a water supply because of contamination and does not have the potential through treatment to be used as a drinking water supply, the Regional Administrator will determine the applicable ground water criteria on a case-by-case basis. In making these determinations, the Regional Administrator will consider localized conditions as well as the future intended uses of the ground water.

For all of the above categories, if the existing

concentrations of any pollutant parameter are at a higher level in the receiving ground water than allowed by the applicable criteria, further increases in concentration of that parameter shall not be allowed. Furthermore, any public drinking water standards for raw or untreated drinking water supplies that are hereafter issued by EPA to prescribe maximum allowable limits or permissible concentrations of chemicals, pesticides, bacteriological quality, or other parameters will apply as required.

Grant applications involving land application techniques will be evaluated with the procedures established in an EPA Technical Bulletin entitled "Evaluation of Land Application Systems, EPA-430/9-75-001." The specific engineering details and monitoring requirements are the subject of that manual. The following information is presented for informational purposes and as design criteria.

A. Land Application Techniques

The following discussion is largely based on "Wastewater Treatment and Reuse by Land Application," written by Charles Pound and Ronald Crites of Metcalf and Eddy, Inc. under contract to EPA.

Irrigation, overland flow, and infiltration-percolation, the three basic approaches to land application, are shown schematically in Figure 1. Their major characteristics are listed in Tables 1 and 2 and Figure 2. In all three approaches wastewater may be applied by spraying or other surface application techniques, such as leaching fields and evaporation ponds.

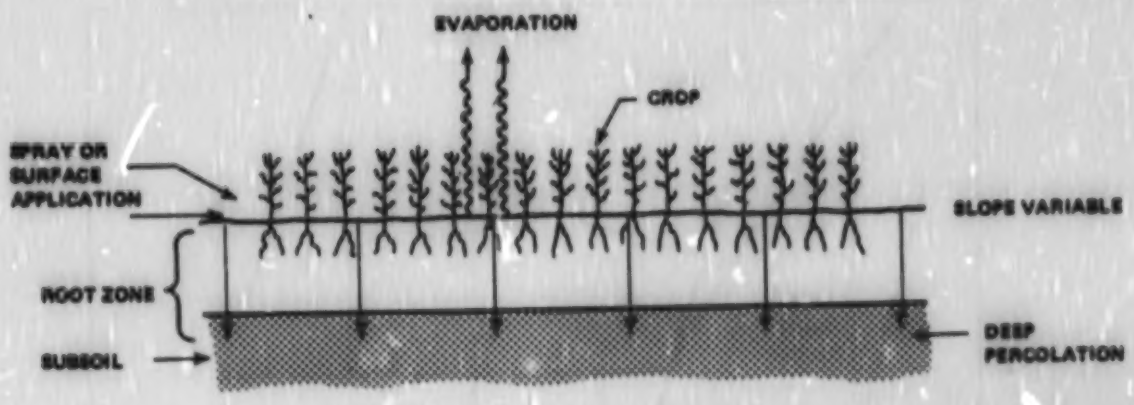
Municipal wastewater, usually pretreated to some extent, has been applied to land mainly by irrigation and infiltration. Recently, municipal installations have begun to experiment with overland flow. Industrial wastewater, generally screened or settled, has been applied using all three approaches, with the choice usually dependent on the type of soil nearby.

Irrigation

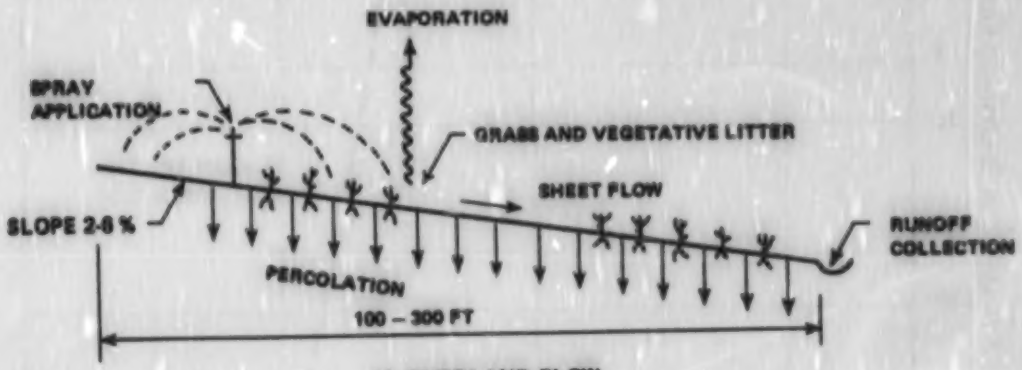
Irrigation is the most widely used type of land application; between 100 and 450 U. S. communities practice this approach. The controlling

Table 1. COMPARATIVE CHARACTERISTICS OF LAND-APPLICATION APPROACHES

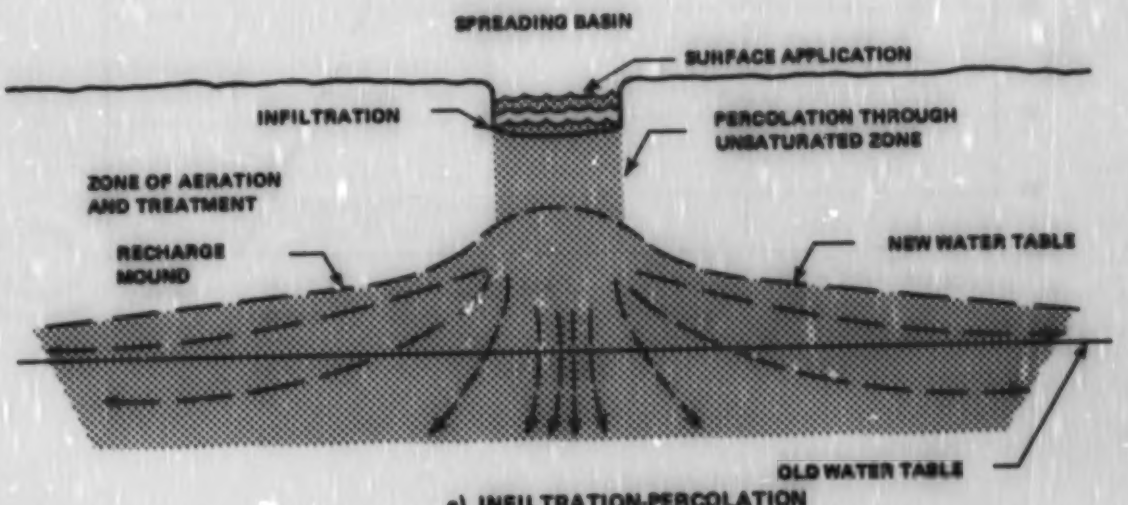
Factor	Type of Approach		
	Irrigation	Overland Flow	Infiltration-percolation
Liquid-loading rate	0.5 to 4 in/wk	2 to 5.5 in/wk	0.3 to 1.0 ft/wk
Annual application	2 to 8 ft/yr	8 to 24 ft/yr	18 to 500 ft/yr
Land required for 1-MGD flow	62 to 580 acres plus buffer zones	48 to 140 acres plus buffer zones	2 to 62 acres plus buffer zones
Application techniques	Spray or surface	Usually spray	Usually surface
Soils	Moderately permeable soils with good productivity when irrigated	Slowly permeable soils such as clay loams and clay	Rapidly permeable soils such as sands, loamy sands, and sandy loams
Probability of influencing groundwater quality	Moderate	Slight	Certain
Needed depth to groundwater	About 5 ft	Undetermined	About 15 ft
Wastewater losses	Predominantly evaporation or deep percolation	Predominantly surface discharge but some evaporation and percolation	Percolation to groundwater



a) IRRIGATION



b) OVERLAND FLOW



c) INFILTRATION-PERCOLATION

Figure 1. LAND APPLICATION APPROACHES

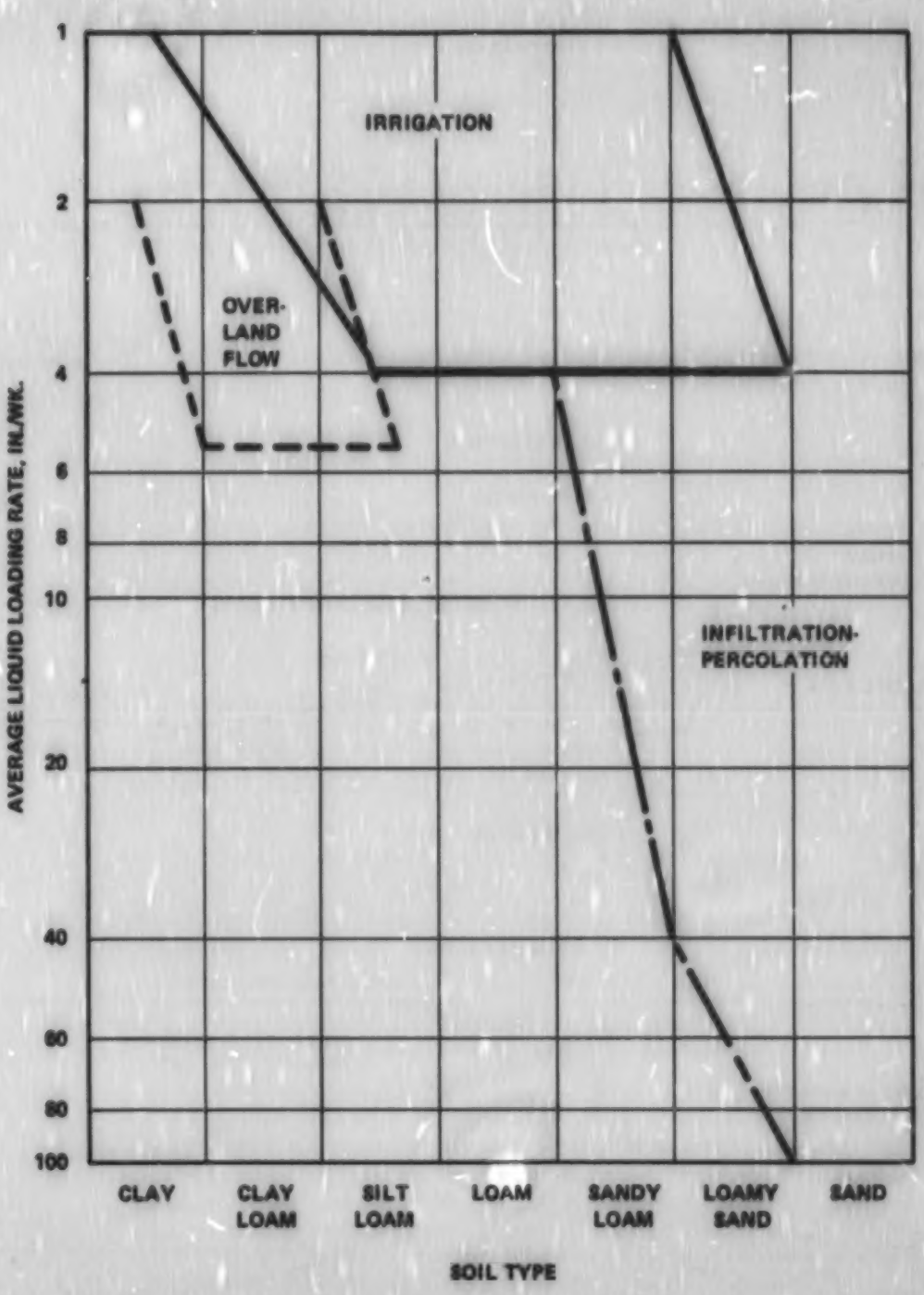


Figure 2. SOIL TYPE VERSUS LIQUID-LOADING RATES FOR DIFFERENT LAND-APPLICATION APPROACHES

Table 2. COMPARISON OF POTENTIAL OBJECTIVES FOR LAND-APPLICATION APPROACHES FROM THE LITERATURE

Objective	Type of Approach		
	Irrigation	Overland Flow	Infiltration-percolation
Use as a treatment process with a recovery of treated water	Generally impractical	50 to 80% recovery	Up to 90% recovery
Use for treatment beyond secondary:			
1. For BOD and suspended solids removal	90-99%	90-99%	90-99%
2. For nitrogen removal	85-90%	70-90%	0-80%
3. For phosphorus removal	80-99%	50-80%	70-95%
Use to grow crops for sale	Excellent	Fair	Poor
Use as direct recycle to the land	Complete	Partial	Complete
Use to recharge groundwater	0-30%	0-10%	Up to 90%
Use in cold climates	Fair[a]	--[b]	Excellent

[a]Conflicting data—woods irrigation acceptable, cropland irrigation marginal.
[b]Insufficient data.

factors in this type of land application are site selection and design, methods of irrigation, loading rates, management and cropping practices, and the expected treatment or removal of wastewater constituents.

The major factors involved in site selection are type, drainability, and depth of soil; nature, variation of depth, and type of underground formation; topography; and considerations of public access to the land. Climate is as important as the land in the design and operation of irrigation systems. It is not a variable, however, because feasible sites must be within economic transmission distance of the source.

Table 3 lists major factors and generalized criteria for site selection. Soil drainability is perhaps the primary factor. Agricultural extension service advisers or adjacent farmers should be consulted about drainability of cropland, and university specialists should be consulted for forest or landscape irrigation. The drainability is important because, coupled with the type of crop or vegetation selected, it directly affects the liquid loading rate. The ideal is a moderately permeable soil capable of infiltrating approximately 2 inches per day or more on an intermittent basis. In general, soils ranging from clay loams to sandy loams are suitable for irrigation. Soil depth should be at least 2 feet of homogenous material and preferably 5 to 6 feet throughout the site. This depth is needed for extensive root development of some plants, as well as for wastewater treatment.

For crop irrigation, slopes are generally limited to about 10 percent or less, depending upon the type of farm equipment to be used. Heavily foliated hillsides up to 30 percent in slope have been spray-irrigated successfully.

A suitable site for wastewater irrigation would preferably be located in an area where contact between the public and the irrigation water and land is limited. However, this criterion is often impossible to meet in landscape irrigation.

Spray, ridge and furrow, and flood are three

Table 3. SITE SELECTION FACTORS AND CRITERIA FOR IRRIGATION

Factor	Criterion
Soil type	Loamy soils preferable, but most soils from sands to clays are acceptable
Soil drainability	Well-drained (more than 2 in./day) soil preferred; consult experienced agricultural advisers
Soil depth	Uniformly at least 5 to 6 ft throughout site
Depth to groundwater	Minimum of 5 ft at all times
Groundwater control	May be necessary to ensure treatment if water table is less than 10 ft from surface
Groundwater movement	Velocity and direction must be determined
Slopes	Up to 15% are acceptable with or without terracing
Underground formations	Should be mapped and analyzed with respect to interference with groundwater or percolating water movement
Isolation	Moderate isolation from public preferable, the degree depending on wastewater characteristics, method of application and crop
Distance from source of wastewater	Economics

basic methods of irrigating. Spray irrigation may be accomplished using a variety of systems from portable to solid-set sprinklers. Ridge and furrow irrigation consists of applying water by gravity flow into furrows; relatively flat land is groomed into alternating ridges and furrows, with crops grown on the ridges. Flood irrigation is the inundation of land with several inches of water. The type of irrigation system used to maintain the specified ground water quality objectives depends on soil drainability, crop, topography, climate, and economics.

The important loading rates are liquid loading in terms of inches per week, and nitrogen loading in terms of pounds per acre per year. Organic loading rates are less important if an intermittent application schedule is followed. Liquid loadings should not exceed the infiltration capacity of the soil and may range from 0.5 to 4.2 inches per week depending on soil, crop, climate, and wastewater characteristics. Crop requirements generally range from 0.2 to 2.0 inches per week, although a specific crop's water needs will vary throughout the growing season. Typical liquid loadings are from 1.5 to 4.0 inches per week. Although wastewater irrigation rates have ranged up to 7 or 8 inches per week, a generalized division between irrigation and infiltration-percolation systems is 4 inches per week.

Nitrogen-loading rates have been calculated because of nitrate buildup in soils, underdrain waters, and ground waters. To minimize such buildup, the weight of total nitrogen applied in a year should not greatly exceed the weight removed by crop harvest. With loamy soils, the permissible liquid-loading rate will be the controlling factor in most cases; for more porous, sandy soils the nitrogen-loading rate may be the controlling factor.

Crop selection can be based on several factors: high water and nutrient uptake, salt or boron tolerance, market value, or management

requirements. Popular crop choices are grasses with high year-round uptakes of water and nitrogen and low maintenance requirements. A drying period ranging from several hours each day to several weeks is required to maintain aerobic soil conditions. The length of time depends upon the crop, the wastewater characteristics, the length of the application period, and the texture and drainage characteristics of the soil. A ratio of drying to wetting of about 3 or 4 to 1 should be considered a minimum.

Treatment of the wastewater often occurs after passage through the first 2 to 4 feet of soil. The extent of treatment is generally not monitored; when it is, however, removals are found to be on the order of from 20 to 99 percent for BOD, suspended solids, and bacteria. As irrigation soils are loamy with considerable organic matter, the heavy metals, phosphorus, and viruses have been found to be nearly completely removed by adsorption. Nitrogen is taken up by plant growth; if the crop is harvested, the removals can be on the order of 90 percent.

Wastewater irrigation has been shown to have a long, useful life, e. g., the systems at Cheyenne, Wyo., operating since 1881; at Fresno, Calif., since 1891; and at Bakersfield, Calif., since 1912.

Wastewater treatment is quite effective at direct recycling of pollutants to the land. Irrigation has had many positive effects on the environment, such as providing wildlife habitats when public access is properly managed. In general, irrigation is considered the most reliable approach to land application of wastewater.

Capital costs for irrigation include those for land, pretreatment, transmission, and distribution. Operating and maintenance costs are for labor, maintenance, and power. The direct economic benefits from irrigation can offset some of the operating costs. The information reported below provides an indication of the range of costs for existing systems and does not necessarily reflect the costs of meeting the BPWTT criteria for land application systems.

Land costs vary tremendously, but a typical current price is $500 per acre. Pretreatment costs for a 1-million-gallon-per-day (MGD) system range from 2.7 cents per 1,000 gallons for screening to 34.6 cents per 1,000 gallons for activated sludge. These costs are totals determined by adding amortized capital costs (25 years at 7 percent) to operating and maintenance costs. The figures are updated to January 1973.

Capital costs for spray irrigation for 10 Michigan sites in 1972 ranged from $1,000 to $5,000 per acre. Costs reported for cannery waste-disposal systems (in 1971) varied from $200 to $2,300 per acre. A cost (in 1967) for a 1-MGD system on 129 acres of $2,700 per acre was also reported; the amortized cost (20 years at 6 percent) was 10 cents per 1,000 gallons of wastewater treated.

For spray sites the reported costs were $800 per acre (in 1966) for the solid set system at Idaho Supreme; $1,500 per acre (in 1966) for golf course irrigation at Moulton-Niguel in Southern Calif.; and $140 per acre (in 1968) for a center pivot rig at Portales, N. M.

Reported operating and maintenance costs, including pretreatment, for six municipal systems varied from 2.7 to 11.6 cents per 1,000 gallons. The costs for six industrial-wastewater systems ranged from 7.3 to 23.9 cents per 1,000 gallons in 1972. The higher operating costs were for canneries operating on a seasonal basis. Estimated cost for spraying hardboard wastes is 5 cents per 1,000 gallons.

At the Mount Vernon Sanitary District in California, costs for a 1,000-acre ridge-and-furrow irrigation system (in 1953) were $75 per acre, including leveling, preparation, and fertilizing. Other plants reported ridge and furrow capital costs of $300 per acre for a Minnesota creamery (in 1950) and $2,000 per acre for a Wisconsin creamery (in 1954).

Operating and maintenance costs at Beardmore, Canada (in 1958) were 12.7 cents per 1,000 gallons. Costs at the Green Giant Co. cannery in Montgomery, Minn. (in 1953) were 22.2 cents per 1,000 gallons.

Provided that the land is relatively level, capital costs for flood irrigation will be less than for spray or ridge and furrow. Capital costs, however, were not reported in the literature. Operating and maintenance costs for flooding at Abilene, Tex., were 7 cents per 1,000 gallons and at Woodland, Calif., 4.2 cents. Both costs include pretreatment.

Cities using irrigation derive direct benefits in different ways. At Woodland, Calif., the city's land is leased for $23 per acre per year for summer irrigation; in addition, a duck club pays about $6 per acre per year for the same land for duck-hunting privileges in late fall. At Abilene, Tex., city land is leased for $12 per acre per year, and additional effluent is provided to adjacent farms. Pomona purchases treated wastewater from the Los Angeles County Sanitation Districts at $7 per acre-foot and sells it to various users at $5 to $22 per acre-foot. San Angelo, Tex. operates a 750-acre city farm at an annual profit of $30 per acre.

Overland Flow

In overland flow the land is sloping, the water runs off, and the crop is not always harvested.

Overland flow has been used for some time.

The method has been tried experimentally on municipal wastewater at Ada, Okla., but it has been more completely developed for use in the United States on food-processing wastewater. The important factors in overland flow are site selection, design loadings, management practices, and treatment to be expected. If the runoff water is collected and discharged into a navigable water, it will have to meet the treatment and discharge criteria.

Soils suited to overland flow are clays and clay loams with limited drainability. The land should have a slope of between 2 and 6 percent, so that the wastewater will flow in a sheet over the ground surface. Grass is planted to provide a habitat for the bacteria which help purify the wastewater. As runoff is expected, suitable surface waters should be nearby to receive the discharge.

Because ground water will not likely be affected by overland flow, it is of minor concern in site selection. The ground water table should be deeper than 2 feet, however, so that the root zone is not waterlogged.

Even though climatic constraints have not been thoroughly tested, systems are being operated in Calif., Tex., Ohio, Pa., Ind., and Md. A system is being considered which will attempt to use overland flow when the ground is frozen. At Melbourne overland flow is used only during the mild winters when evaporation is low.

Overland flow systems are generally designed on the basis of liquid-loading rates, although an organic-loading or detention-time criterion might be developed in the future. The process is essentially biological, with a minimum contact time between bacteria and wastewater required for adequate treatment. Liquid-loading rates used in design have ranged from 2.5 to 5.5 inches per week, with a typical loading being 4 inches per week. At Ada the optimum loading has been around 4 inches per week, while at Melbourne it is 5.2 inches per week.

Management practices important in overland flow are maintaining the proper hydraulic loading cycle (periods of application followed by resting), maintaining an active biota and a growing grass, and monitoring the performance of the system. Hydraulic loading cycles have been found to range from 6 to 8 hours of spraying followed by 6 to 18 hours of drying. Periodic cutting of the grass with or without removal is important, but the effects on organic oxidation have not been fully demonstrated. Loading cycles must be monitored for maximum removal efficiencies.

Treatment of wastewater by overland flow is only slightly less complete than for irrigation. The overland flow systems at Melbourne and Ada (both using municipal wastewater) and at Paris, Tex. (using industrial wastewater) have been monitored to determine removal efficiencies. The results suggest BOD and suspended solids removals of from 95 to 99 percent, nitrogen removals of from 70 to 90 percent, and phosphorus removals of from 50 to 60 percent. Solids and organics are removed by biological oxidation of the solids as they pass through the vegetative litter. Nutrients are removed mainly by crop uptake. Other removal mechanisms for nutrients include biological uptake, denitrification, and fixation in the soil.

Less is known about the useful life of an overland flow system than about an irrigation system. The Melbourne system has been operating successfully for many years as a wintertime alternative to irrigation. The oldest operating system in this country, however, has been treating industrial wastewater for less than 20 years. Analysis of the literature suggests that an indefinite useful life may be possible if effective management continues.

Adverse environmental effects should be minimal. As a runoff flow is created, it must be stored, reused, or discharged to a surface watercourse. As infiltration into the soil is slight, the chances of affecting ground water quality are low.

Cost data on overland flow facilities are scarce because of the limited number of overland flow sites in operation. Capital costs include land, pretreatment, transmission, earthwork, distribution, and collection. Land costs are quite variable; even at the Paris site, they varied from $50 to $600 per acre for the 500 acres purchased. Pretreatment generally consists of screening. Transmission generally is by pumping.

Earthwork will vary with the original topography of the site. At Paris, the rolling land was regraded at a cost of $306 per acre for clearing, $108 per acre for grass cover, and $188 per acre for miscellaneous work. On the other hand, complete regrading of flat land to 2.5 percent slopes at the Hunt-Wesson Co. site in Davis, Calif. cost $1,500 per acre.

The original distribution system for Paris cost $348 per acre to install. The cost (in 1971) for the piping at the Davis site was about $1,250 per acre. Collection systems for the runoff are normally included under earthwork. At Davis the collection ditches amounted to 10 percent of the earthwork cost, or about $150 per acre.

At Paris, the annual operational cost is 5 cents per 1,000 gallons. The operational cost is reduced slightly by the income of 0.4 cent per 1,000 gallons from crops produced on the site. At Davis the annual cost is 5 to 10 cents per 1,000 gallons.

Infiltration-Percolation

Infiltration-percolation had been used with moderate loading rates (4 to 12 inches per week) as an alternative to discharging effluent to surface waters. High-rate systems (5 to 8 feet per week) have been designed to recharge ground water. Because high-rate systems have been carefully designed and monitored, they will be stressed in the following discussion.

Soil drainability on the order of from 4 to 12 inches per day or more is necessary for successful use of infiltration-percolation. Acceptable soil types include sand, sandy loams, loamy sands, and gravels. Very coarse sand and gravel are less desirable because they allow wastewater to pass too rapidly through the first few feet, where the major biological and chemical action takes place.

Other factors of importance include deep percolation rates; depth, movement, and quality of ground water; topography; and underlying geologic formations. To control the wastewater after it infiltrates the surface and percolates through the soil matrix, the subsoil and aquifier characteristics must be known. Recharge should not be attempted without specific knowledge of the movement of the water in the soil system.

Organic-loading rates of municipal systems range from 3 to 15 tons of BOD per acre per year. Industrial systems have operated successfully at 90 tons. Municipal systems generally pretreat the wastewater to secondary quality to maintain high liquid-loading rates. Industries have tended to rely more on the assimilative capacity of the soil, generally using pretreatment only to avoid operational problems.

Management practices important to infiltration-percolation systems include maintenance of hydraulic loading cycles, basin surface management, and system monitoring. Intermittent application of wastewater is required to maintain high infiltration rates, and the optimum cycle between inundation periods and resting periods must be determined for each individual case. Basin surfaces may be bare or covered with gravel or vegetation. Each type of surface requires some maintenance and inspection for a satisfactory operation. Monitoring, especially of ground water levels and quality, is essential to system management.

The filtering and straining action of the soil are excellent, so suspended solids, bacteria, and BOD are almost completely removed in most cases. Nitrogen removals are generally poor unless specific operating procedures are established to maximize denitrification. Phosphorus removals range from 70 to 90 percent, depending on the percentage of clay or organic matter in the soil matrix which will adsorb phosphate ions.

Wastewater treatment by infiltration-percolation varies considerably with soil characteristics and management practices. By careful management of the hydraulic loading cycle (2 to 3 weeks of wetting, 2 weeks of drying), Flushing Meadows, Ariz. has obtained nitrogen removals up to 80 percent. Overall nitrogen removal, taking into account the high nitrate concentration flushed to the ground water at the beginning of inundation, averaged 30 percent. Removals of phosphorus and heavy metals were also generally less than for irrigation.

The useful life of an infiltration-percolation system will be shorter, in most cases, than that of irrigation or overland flow. This is caused by unacceptably high loadings of inorganic constituents, such as phosphorus and heavy metals, and by the fact that these constituents are fixed in the soil matrix and not positively removed. Therefore, exhaustion of the fixation capacity for phosphorus and heavy metals will be a function of the loading rate and the fixation sites available. At Lake George, N. Y., phosphorus retention on the basis of recent monitoring in some percolation beds appears to have been exhausted. The system had been operating about 35 years at moderate rates of from 7 to 15 inches per week.

From the standpoint of environmental effects, infiltration-percolation is the least reliable of the three approaches relative to the best practicable criteria. However, most systems that have been monitored and managed properly proved to be quite reliable.

Capital and operating costs for infiltration-percolation systems will generally be less than those for irrigation or overland flow because less land is used and distribution is by gravity flow. For high-rate systems, however, pretreatment needs are substantially greater.

The capital costs for infiltration-percolation are for land, pretreatment, earthwork, transmission and distribution, and recovery. At Westby, Wis., basins were constructed in a 5 percent hillside. The land cost was $750 per acre; earthwork was $2,500 per acre. The earthwork cost at Flushing Meadows was $4,500 per acre. Others have calculated the cost of transmission and distribution at Flushing Meadows at $96,000. The recovery wells there cost $35 per foot, or $17,500 for each well.

Operation and maintenance costs for infiltration-percolation systems consist of costs for labor, maintenance, and power. At Flushing Meadows, the operating cost is 2.4 cents per 1,000 gallons, while at Whittier Narrows, Calif., it is 2.7 cents.

Simpson Lee Paper Co. operates two pulp and paper waste-disposal systems by infiltration-

percolation. At Vicksburg, Mich., 1 inch per day is applied by spraying. The operating cost is 2.9 cents at Vicksburg. Pretreatment costs for primary settling are included.

Other Land Application Techniques

There are several other approaches to land application, including subsurface leach fields, deep-well injection, and evaporation ponds. Such techniques are generally limited in their applicability. Leach fields are prevalent in rural areas for small systems involving septic tanks and are unlikely to become more widespread. Deep-well injection provides no substantial renovation to the wastewater and is not allowed by the best-practicable-treatment criteria unless pretreatment is of a sufficiently high quality. Evaporation ponds also have limited applicability because of their large land requirements and climatic constraints, but some are in use.

B. Land Utilization Techniques

Wastes and sludges from wastewater treatment plants are often ultimately disposed of on the land by such processes as surface spreading or landfill disposal of dewatered and stabilized sludge, landfill disposal of incineration ash, and composting.

Land Spreading of Sludge

Land spreading of either chemically- or biologically-stabilized sludge is generally similar to the land application of wastewater. Occasionally, land spreading is limited by the ability of the land to accept the large amounts of water in the sludge. More often it is limited by the ability of the land to accept high concentrations of salts, organic matter, heavy metals, and pathogenic organisms.

Sludge can be applied by spray or ridge and furrow irrigation. Procedures used in land application techniques are followed for site selection and cropping. Likewise, the amount of nitrogen compounds, nitrates and ammonia, is expected to be limiting. Ammonia may have to be reduced prior to application. Ammonia may interfere with seed germination, and nitrates may reach the ground water.

In Great Britain 20 to 30 communities practice land spreading. The solids content of the stabilized sludge varies between 2 and 5 percent. The application of less than 5 tons of dry solids per acre per year has been successful. Monitoring of heavy metals has not revealed problems at this level of application.

The Chicago Metropolitan Sanitary District is now spraying sludge on 7,000 acres. The land is prepared by leveling to less than 5 percent grade and building earth berms to control runoff. Application rates of 2 inches of sludge per year are expected to be successful. At higher rates, nitrogen compounds would have to be removed. Aeration techniques have been studied and should be successful in oxidizing ammonia nitrogen.

Another method of land spreading involves application of dried sludge, which contains less nutrient, namely nitrogen. When the dry sludge is packaged, as it is in Milwaukee, Wis., it can be sold as a soil conditioner. This conserves space in land disposal sites.

Landfill of Sludge

Stabilized sludge, which has been adequately dewatered, can be disposed of by sanitary landfill, the controlled burial of waste beneath an earth cover. Sufficient land must be available, runoff and percolation of the leachate to the groundwater must be controlled and monitored, and odors and pathogenic problems must be dealt with. The U.S. Department of Agriculture is experimenting with a variety of sludges, successfully burying the sludges in 2-foot-wide, 2- to 4-foot deep trenches with a 1-foot soil cover. Other methods such as deep disking and rotary tilling will also be tested.

Another method of disposal is sanitary landfilling liquid sludge mixed with solid waste. In addition to the safeguards cited above, careful consideration must also be given to the site characteristics and the nature and quantity of the waste when designing for this method of disposal.

Landfill of Incinerator Ash

Where land is scarce or distant, incineration is often an economically attractive method for disposing of treatment-plant sludge. The ash from incinerated municipal sludges is only from 3 to 10 percent of the mass of dewatered sludge cake, and incineration reduces odors and pathogens. The stack discharges to the atmosphere and the air environmental concerns must be properly addressed.

Composting and Final Disposal

Sewage sludge can be decomposed by composting, an aerobic digestion process that converts organic material into a soil conditioner. Moisture content of the sludge is reduced to approximately 50 percent. Biological action heats the sludge to an average temperature over 70° C. for an excess of 5 days. Nearly all pathogenic organisms are destroyed. The end product can be applied to the land or put into a sanitary landfill.

C. Nonpoint Sources of Pollutants

Information on nonpoint sources of pollutants, such as runoff from agriculture, construction,

and mining activities is being published pursuant to Section 304(e) of the Act. However, the information and techniques discussed in that publication should be an integral part of the total area-wide waste management system. All techniques of water pollution abatement should be considered in area-wide programs to arrive at the best practicable treatment.

CHAPTER IV:
WASTE MANAGEMENT TECHNIQUES INVOLVING TREATMENT AND DISCHARGE

There are an estimated 21,118 publicly-owned treatment works (POTW's) in the United States employing different methods of treatment (Table 4). Treatment and discharge is the technique used by the largest number of such facilities.

The development of treatment and discharge technology follows a basic pattern (Figure 3): Raw discharge, primary treatment, secondary treatment, advanced waste or tertiary treatment for nutrient removal, and renovation. The initial goal of the Act requires that POTW's utilizing treatment and discharge meet secondary treatment as defined by EPA by July 1, 1977 or June 1, 1978 (for new construction). The second goal of the Act is to provide application of best practicable treatment by July 1, 1983.

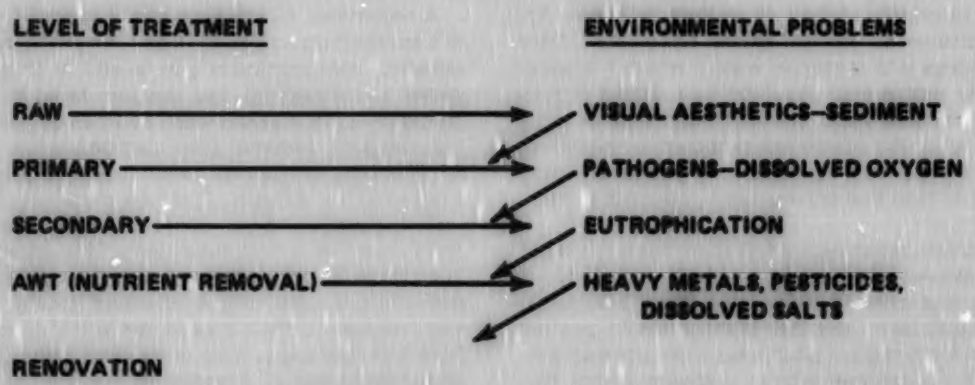


Figure 3. ENVIRONMENTAL PROBLEMS ASSOCIATED WITH TREATMENT AND DISCHARGE

Table 4. ESTIMATED DISTRIBUTION OF PUBLICLY-OWNED TREATMENT WORKS

	Major Plants (1 MGD or more)			Minor Plants (1 MGD or less)		
	WQL[a]	EL[b]	EL-OO[c]	WQL	EL	Total
None	29	32	3	944	1,462	2,467
Primary	549	386	62	828	1,278	3,022
Pond	87	50	7	1,800	2,791	4,728
Trickling Filter	574	382	57	1,367	2,016	4,338
Activated Sludge	235	219	35	872	1,162	2,468
Extended Aeration	42	29	4	696	1,071	1,828
Secondary-Other	112	77	13	518	879	1,586
Land Disposal	5	3	–	58	91	157
Tertiary	42	30	4	169	263	504
Total	1,676	1,188	185	7,242	11,012	21,118

[a]Plants located on water-quality-limited segments.
[b]Plants located on effluent-limited segments.
[c]Plants located on effluent-limited segments with ocean outfalls.

Criteria for best practicable treatment must be environmentally sound as well as technologically achievable. The areas of concern which are likely to warrant additional attention after the application of secondary treatment controls in 1977 include oxygen-demanding material, nutrients which contribute to eutrophication (phosphorus and nitrogen), heavy metals, pesticides, and dissolved solids.

Review of the literature and existing water quality surveys indicates that protection of the dissolved oxygen in receiving waters has the highest priority in the vast majority of cases. Approximately 50 percent of the Nation's POTW's discharge into receiving waters where the water quality problem is unsolved by existing regulations. In these water-quality-limited segments, almost all of the plants are expected to require an effluent containing less oxygen-demanding material than that achievable by secondary treatment.

Eutrophication typically occurs mainly in lakes and slow-moving estuaries. A recent study reveals that only 15 percent of the POTW's discharge to lakes, and half of these (or 7.5 percent of the total) require phosphorus control and one-third (or 5 percent) require nitrogen control. River and estuary needs for nutrient control have not presently been surveyed on a national scale.

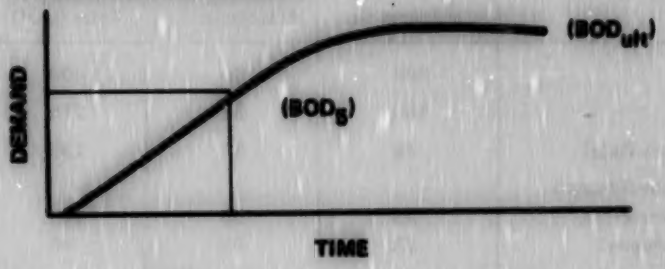
The fecal coliform standards as established by the secondary treatment criteria were set at levels which would ensure the highest recreational (primary contact recreation) use.

The parameter used in secondary treatment to measure oxygen-demanding material in waste is 5-day biochemical oxygen demand (BOD_5). The BOD_5 test essentially measures the oxygen demand of only the carbonaceous organic material in the wastewater effluent. It usually does not measure the oxygen demand of the nitrogenous organic material, which exerts its effect in the test later than the carbonaceous material (Figure 4).

A parameter, ultimate oxygen demand (UOD), is a superior parameter for measuring the oxygen demand from municipal plants and is thus superior in protecting the oxygen level of the stream since it includes both sources of biological oxygen demand (the carbonaceous and nitrogenous) and allows credit for any dissolved oxygen in the effluent. A similar parameter, ultimate biological oxygen demand (UBOD), can be used where no nitrogenous demand is expected. A third useful parameter to evaluate oxygen demand is chemical oxygen demand (COD). This test measures carbonaceous demand for oxygen from both biodegradable and nonbiodegradable compounds and is intended to prevent the discharge of slowly-degrading industrial waste. Consideration should be given to COD in effluents from POTW's which receive substantially nonbiodegradable industrial wastes.

SOURCES

CARBONACEOUS DEMAND



$$BOD_{ult} = 1.5\ (BOD_5)$$

NITROGENOUS DEMAND

$$NH_3 + 2O_2 = H^+ + NO_3^- + H_2O$$

$$NH_3 - N = 14;\ O_2 = 64$$

$$NOD_{ult} = \frac{64}{14}\ (NH_3\ N) = 4.6\ (NH_3 - N)$$

CREDIT

DISSOLVED OXYGEN = 1.0 (DO)

NOTE:
K_1 IS GENERALLY 1.5
K_2 IS GENERALLY 4.6

FORMULAS

$$UOD = K_1\ (BOD_5) + K_2\ (NH_3N) - 1.0\ (DO)$$

$$UBOD = K_1\ (BOD_5) - 1.0\ (DO)$$

Figure 4. DERIVATION OF ULTIMATE OXYGEN DEMAND (UOD)

Carbonaceous oxygen demand is the largest source of biological-oxygen demanding-material in effluents from raw discharge or primary treatment (Table 5). In secondary treatment (high-rate system, as defined by EPA, the nitrogenous demand is by far the largest residual demand in the effluent. Thus, UOD as a means of measurement is particularly useful.

In addition to the treatment of wastewaters which pass through municipal plants, other approaches to improve water quality have been examined, including treating combined sewer overflows, treating storm water, and controlling nonpoint sources. Demonstrated technology to control storm water and nonpoint sources essentially does not exist. Efforts are being made to

Table 5. TYPICAL VALUES OF ULTIMATE OXYGEN DEMAND (UOD)

	Carbonaceous	Nitrogenous	Total (UOD)	% Removal
Raw	300	100	400	0
Primary	180	95	275	31
Secondary (High-Rate)	45	90	135	66
Secondary (Conventional)				
(Winter)	23	90	113	74
(Summer)	23	23	46	88
Two-Stage Nitrification	23	23	46	88
Advanced Waste Treatment	8	12	20	95

Table 6. YEARLY CAPITAL COST OF INCREASED TREATMENT AND COMBINED SEWER OVERFLOW CONTROL IN SELECTED CITIES

	Estimated Increased Treatment Cost[a] ($/pound UOD Removed/yr)	Overflow Controls Cost ($/pound UOD Removed/yr)
Cleveland, Ohio	0.21	2.22 (Filtration)
Oakland, Calif.	0.39	13.70 (Holding tanks) 13.80 (Sewer repair) 8.80 (Fine screening) 8.80 (System control)
Atlanta, Ga.	0.19	28.00 (Separate systems) 0.51 (Storage and screening) 1.84 (Storage and chlorination)
Bucyrus, Ohio	0.48	42.10 (Separate systems) 8.35 (Lagoons) 27.00 (Primary treatment)
New York City, N.Y.	0.98	21.20 (Overflow control)
Kenosha, Wis.	0.22	11.80 (Storage and treatment) 23.80 (Storage and treatment)
Sacramento, Calif.	0.37	22.80 (Storage and treatment)
Chippewa Falls, Wis.	0.46	19.80 (Storage and treatment)

[a]Additional capital cost over secondary treatment to achieve seasonal nitrification.

quantify the problems and identify the effects on receiving waters.

The combined sewer overflow problem is better quantified, and EPA research has demonstrated many types of treatment and control systems. On an amount basis, the cost of removing oxygen-demanding material by combined sewer overflow treatment is much greater than the cost resulting from removal by increasing treatment at the plant (Table 6). This is always true on a

Table 7. CAPITAL COST OF INCREASED TREATMENT AND COMBINED SEWER OVERFLOW CONTROL ON A YEARLY AND PER-STORM-ONLY BASIS[a]

	Estimated Increased Treatment Cost[b]	Overflow Control Cost
COST ON A YEARLY BASIS		
Capital Cost	$150,000	$895,000
UOD removed (pounds/year)	324,000	45,000
Cost ($/pound of UOD removed/year)	0.46	19.80
COST ON A PER-STORM-ONLY BASIS		
Capital Cost	$150,000	$895,000
UOD removed during storm only (pounds/storm)	111	4,905
Cost ($/pound of UOD removed/storm)	1,350	182

[a]Chippewa Falls, Wis., 5 ea. storm.
[b]Additional capital cost over secondary treatment to achieve seasonal nitrification.

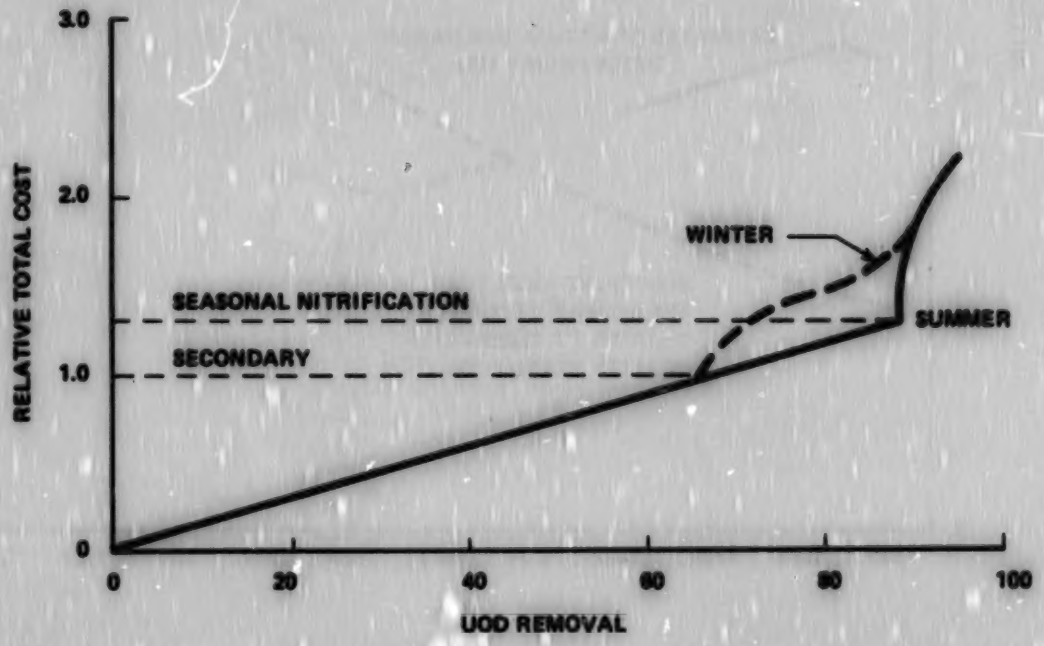


Figure 5. COST VS. PERCENT OF UOD REMOVED

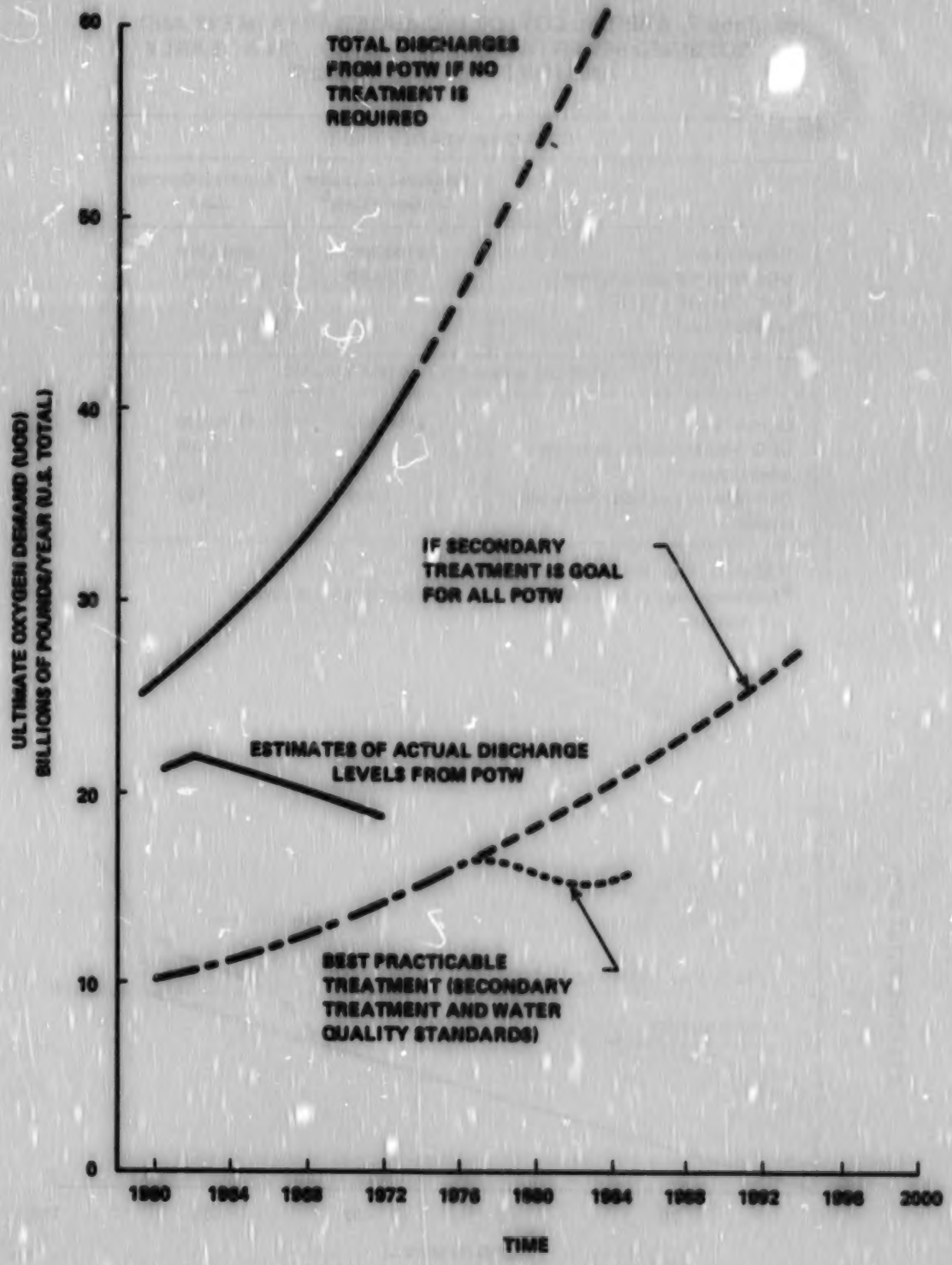


Figure 6. UOD REMOVAL, 1960-2000

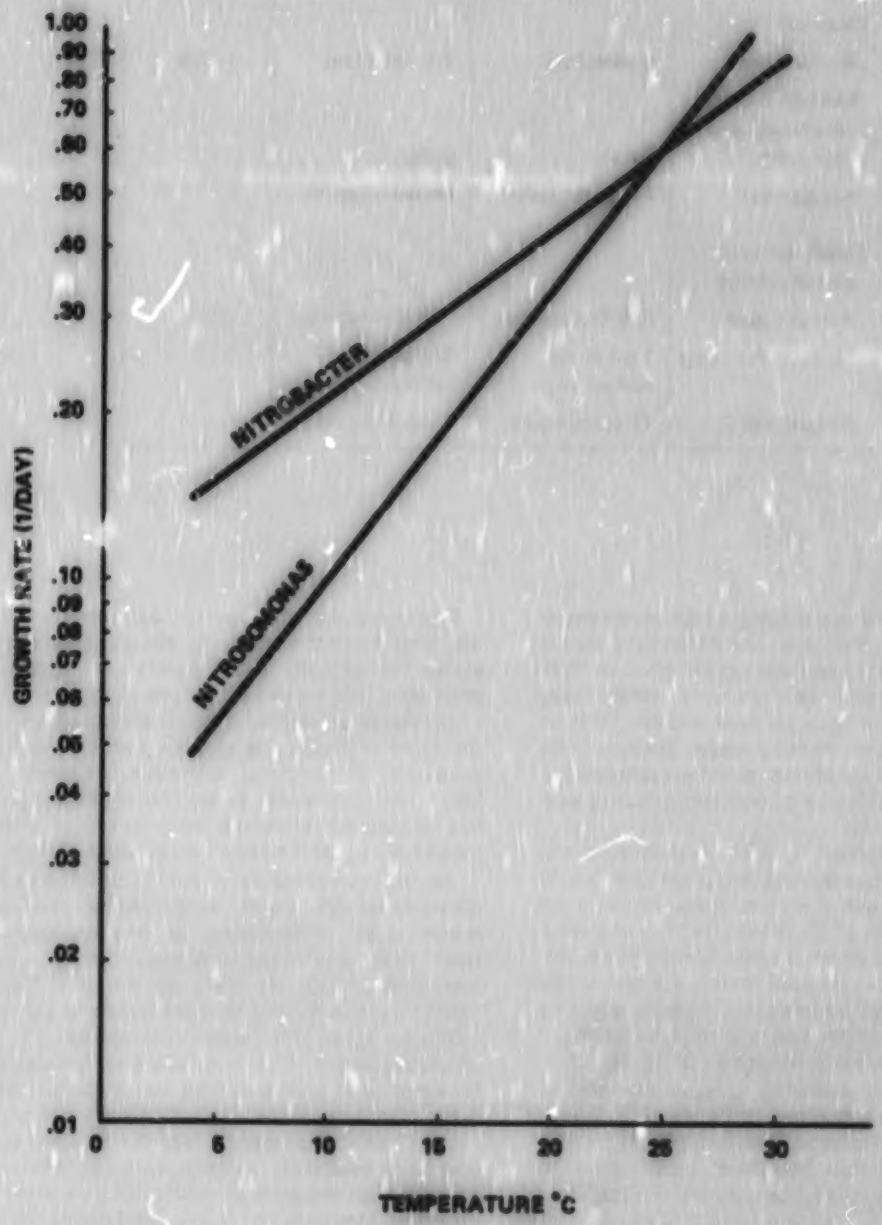


Figure 7. EFFECT OF TEMPERATURE ON THE GROWTH RATE OF NITRIFIERS

Table 8. ENERGY REQUIREMENTS OF ACTIVATED SLUDGE TREATMENT

	Secondary	Seasonal Nitrification	% Increase
Electrical			
Amount used	5 watts/cap	7.5 watts/cap	+ 50%
Percent of total electrical usage for a city	0.4%	0.6%	
Annual cost	44 cents/cap/yr	66 cents/cap/yr	
Fossil fuel to incinerate sludge			
Amount used	370 Btu/cap/day	280 Btu/cap/day	-2.3%
Comparative usage	1 gal of fuel oil/cap/yr	3/4 gal of fuel oil/cap/yr	
Annual cost	12 cents/cap/yr	9 cents/cap/yr	

yearly basis, but it is not always true on an event basis (Table 7). Also, the water quality benefits from overflow treatment are poorly documented. Overflow treatment and control needs vary greatly from one city to the next and can best be handled on a case-by-case basis. Systems with combined sewer overflows must be controlled to minimize the discharge of pollutants during wet-weather conditions.

A study conducted by EPA to determine the level of effluent quality required to ensure that 90 percent of the rivers and streams would meet dissolved oxygen (DO) criteria for fish and wildlife standards in fresh water—5 milligrams per liter (mg/l) of DO—revealed that a yearly average of UOD of 33 mg/l was required. Statistically, this results in an approximate monthly maximum of 50 mg/l and a weekly maximum of 75 mg/l.

The cost for removing oxygen-demanding material from wastewater is economically reasonable up to 88 percent removal (Figure 5). Removals greater than this level result in much higher marginal costs per pound of pollutant removed.

The secondary treatment requirements in combination with water quality standards would offset the increased rate of UOD discharge associated with increased population (Figure 6).

The rate of biological oxygen removal resulting from the nitrifying action of ammonia varies dramatically with temperature (Figure 7). With very cold waters (either receiving waters or in wastewater being treated biologically), the nitrification process is slowed, reducing the importance of removing ammonia. However, in lakes and reservoirs where the water temperature increases, ammonia becomes more important and may still require year-round control.

As the environmental significance of ammonia diminishes with lower temperatures, the economic cost of satisfying its oxygen demand rises. The technology to achieve nitrification is well understood. As early as the late 1920's, plants were designed to accomplish 88 percent UOD removals. The capital and operating costs of seasonal nitrification in biological processes, however, will increase with decreasing wastewater temperature, as a result of decreasing biological nitrification rates. Likewise, in a physical-chemical treatment process such as ammonia stripping, an increase in cost will occur with decreasing temperature. If the nitrification is applied only to wastewaters above 20° C, the cost increase (both capital and operating) will be typically 30 percent greater than the cost of achieving secondary treatment. The cost of year round

nitrification would be 75 percent greater than required secondary treatment.

In an EPA study where the discharge was to streams with intermittent or no flow, the nitrified effluents were sufficient to meet fish and wildlife standards in an estimated 90 percent of the cases. However, in only a few cases would secondary treatment levels meet these standards because of excessively low dissolved oxygen and fish toxicity caused by uncontrolled discharge of ammonia.

Nitrification would result in approximately a 50 percent increase in electrical power consumption for municipal waste treatment (Table 8). The resulting total demand for wastewater treatment would be less than 1 percent of the total community demand.

As a tradeoff for electrical demand, nitrification would produce less sludge and reduce fossil fuel requirements for incineration by up to approximately 25 percent (Table 8). Solid-waste management problems are likewise decreased. With a decrease of 25 percent in total sludge production, air pollution problems arising from incineration would be reduced as a result.

A. Flow Reduction

Information on reducing the total flow of sewage is being prepared for a report to Congress pursuant to Section 104(o)(2) of the Act. The techniques discussed in that report should be recognized as part of the total areawide waste management system and essential to achieving the best practicable treatment.

Excluding reuse and recycling, the techniques for reducing total flow of sewage can be placed into four major categories. The first is the reduction of infiltration and inflow into the sewage collection system. Infiltration problems must be solved, according to Section 201(g)(3) of the Act, before a Federal grant can be made. The procedures for complying with this section are contained in the regulations "Grants for Construction of Treatment Works" (40 CFR Part 35.927). The second, the reduction of household water consumption, involves installing devices to reduce water usage in existing household appliances and fixtures as well as designing and installing new appliances and fixtures that use less water. The third category involves economics and pricing policies to reduce use of water. A final technique is to change public attitudes as they relate to water consumption.

B. Techniques to Achieve Secondary Treatment and Nitrification

Extensive information has been available since the 1920's on the biological techniques to achieve the effluent quality required by secondary treatment and nitrification. The techniques fall into four categories: (1) biological treatment, including ponds, activated sludge, and trickling filters; (2) physical-chemical processes, including chemical flocculation, filtration, activated carbon, breakpoint chlorination, ion exchange, and ammonia stripping; (3) land application systems; and (4) systems which combine the previous techniques.

Biological

The most widely used systems of wastewater treatment employ biological treatment. With the exception of anaerobic ponds, the systems use aerobic (air- or oxygen-requiring) metabolism to degrade the pollutants. Oxygen and bacterial cultures can be provided in many ways, including large shallow ponds exposed to the air, trickling filters with a bacterial culture supported on a rock or synthetic medium which is exposed to the atmosphere, and activated sludge, in which the culture of bacteria is aerated with air or oxygen.

Ponds. Sewage oxidation ponds, often called lagoons, are widely used throughout the United States. These systems require little energy because they rely on natural forces such as aeration and produce minimum quantities of sludge. Since the design and operation of ponds vary widely, it is hard to generalize on their capabilities. A multicelled pond with intermittent-discharge capabilities can achieve secondary treatment and best practicable treatment without additional aeration or filtration if average loading does not exceed 20 pounds of BOD_5 per acre per day and if it has at least a 6-month storage capability. However, this is not true of ponds which discharge continuously. Normally, ammonia is readily converted; however, BOD_5 removal and ultimate removal of nitrogen, both of which are dependent upon the effective capture of suspended solids, are more difficult.

Ponds with lesser capabilities can employ mechanical aeration or rely on pretreatment (such as primary sedimentation) or postfiltration to achieve the required levels. High solids carryover, seasonal changes, algae growth, hydraulic short-circuiting, and overload conditions are problems which arise in many ponds and make achieving the standards more difficult.

In the 0.1- to 4.0-M3D size range, total costs for ponds range from $3 to $9 per person per year, versus from $9 to $20 for activated sludge or trickling filters. Where land costs are high, however, ponds lose their cost advantages.

Activated sludge. The activated sludge process consists of an aerator and clarifier and is usually preceded by primary sedimentation.

The aerator, utilizing air (either diffused or mechanical) or pure oxygen, provides conditions for a suspended microbial growth which metabolizes the biodegradable wastes. The microbial growth is clarified and a portion recycled to maintain metabolism in the aerated tankage. The other portion (the build-up of microbial growth) and the primary solids go to an appropriate solids-handling facility. The use of chemicals—lime, ferric and ferrous salts, alum, sodium aluminate, or polymers—can enhance the capture of particulates in both primary sedimentation and secondary clarification, thus improving operation of the process. These techniques are examples of combined biological and physical-chemical treatment.

Activated sludge plants can be operated to establish and maintain bacteria to nitrify ammonia. This can be accomplished by supplying additional aeration, by ensuring that the nitrifying organisms propagate at a faster rate than they are destroyed, and by providing sufficient capacity in the aerator and/or clarifier to handle the higher mass of microbial growth resulting from the reduced wasting rate.

Several other new techniques have been employed to increase the capabilities of activated sludge plants without increasing the size of aerators or clarifiers. Rotating disks have been tested successfully in pilot plants. By using a disk, extra biological solids can be maintained in the aerator. A pilot plant in Tracy, Calif., used a synthetic red wood media to allow a larger culture of bacteria to be maintained in the aerator. A similar facility is operational in San Pablo, Calif.

Separate biological nitrification, which is basically similar to an activated sludge system, can also be used. The biodegradable wastes are largely reduced to approximately secondary quality in preliminary treatment. The aerobic microbial growth is then largely established and maintained on the metabolism of ammonia. A separate nitrification stage is more reliable and can remove ammonia at much colder temperatures than the methods previously discussed. The capital and operational costs are expected to be from 25 to 75 percent greater than those for single-stage systems.

Another new system, tested in pilot plants at Washington, D. C. and Central Contra Costa, Calif., uses chemical treatment to reduce the organic loading to the activated sludge aerator. The pilot results were excellent, with ammonia removed easily and reliably by nitrification. The system, however, does produce high quantities of sludge.

Still another system using combined biological and physical-chemical methods is to employ breakpoint chlorination or ion exchange (both discussed later) to remove the ammonia from a nonnitrifying biological plant to acceptable levels.

Trickling filters. Trickling filter plants are similar to activated sludge plants except that microbial growth is not suspended. Instead it is attached to a fixed medium, such as rocks or a synthetic material, over which the wastewater is repeatedly recycled. The excessive microbial growth is sloughed off the media and captured in a clarifier. Trickling filters employing standard loadings below 10 to 20 pounds of BOD_5 per 1,000 cubic feet of rock medium per day can meet secondary treatment requirements. Synthetic media are available with larger void spaces and greater surface area per cubic foot. These media have been successfully piloted and operated at loading rates of as much as 2 to 5 times that of rock media; they can be operated at higher hydraulic loading rates. The performance and costs are generally competitive with equivalent activated sludge systems.

A modification of the trickling filter concept involves rotating closely packed disks through the sewage. Large masses of bacteria are maintained and aerated on the disk during rotation. Initial work in Passaic Valley, N. J., Pewaukee, Wis., and at the University of Michigan has demonstrated the system's capabilities. The rotating disk can be used in the same variety of applications as rock or synthetic media filters, namely as conventional secondary treatment for bulk removal prior to subsequent treatment (roughing filter) or to achieve nitrification.

Physical-Chemical

Chemical flocculation of suspended and colloidal solids (using lime, ferric or ferrous salts, alum, and sodium aluminate, often with polymer addition and subsequent sedimentation) can often achieve suspended solids effluent quality equivalent to secondary treatment. The dissolved BOD and COD are not substantially removed, and wastewater with high dissolved-organic concentrations may not achieve effluent quality equivalent to secondary treatment without additional treatment.

Suspended solids and the associated BOD can be removed by filtration in any of the methods discussed to improve the effluent quality above secondary treatment. A wide selection of filtration media is available. Either pressure or gravity filtration can be used. Removal of suspended solids is usually desirable prior to activated carbon, breakpoint chlorination, ion exchange, or ammonia stripping.

Activated carbon has proven its ability to adsorb organic material in wastewater. Because activated carbon does not rely on bacterial action, it can remove biodegradable and nonbiodegradable material. Several techniques have been used to bring the activated carbon in contact with the wastewater; various forms of carbon have been used. Granular carbon is the most widely used and highly developed technique. Contact methods include pressurized downflow, gravity downflow, and suspended-bed upflow. Powdered carbon systems can also be used and show excellent potential, although still in a research and development stage.

Breakpoint chlorination (superchlorination) can be used to reduce ammonia concentrations in wastewater. Chlorine, sodium hypochlorite, and calcium hypochlorite can be added at ratios between 7.6:1 and 10:1 of chlorine to ammonia nitrogen. This will oxidize the ammonia to nitrogen gas if reaction takes place at about pH 7. Proper controls and operation must be maintained at all times.

Selective ion exchange systems are available for removal of ammonia. The ion exchange medium normally used is clinotilolite. After regeneration with a salt and/or lime brine, it will exchange either the sodium ion or calcium ion for

Table 9. ESTIMATED COSTS FOR COMPLETE SEPARATION OF STORMWATER AND SANITARY SEWERS

City	Total Project Cost	Cost/acre	Cost/capita
Chicago, Ill.	$2,300,000,000	$17,000	$482
Cleveland, Ohio	470,000,000-700,000,000	12,000-18,000	360-535
Concord, N.H.	8,000,000	.....	280
Detroit, Mich.	1,315,000,000	.....	360
Haverhill, Mass.	30,000,000	10,500	650
Kansas City, Kans.	20,000,000	7,748[a]	187
Lawrence, Kans.	30,000,000	13,500	915
Lowell, Mass.	70,000,000	12,000	780
Milwaukee, Wis.	425,000,000	8,250	440
New Haven, Conn.	10,000,000	16,363[a]	560
New York, N.Y.	4,000,000,000	25,000-30,000	462
Portland, Ore.	100,000,000-280,000,000	2,100-7,700	280-652
Seattle, Wash.	145,000,000	3,850	250
Spokane, Wash.	50,000,000	1,500	415
Toronto, Ontario	285,000,000	17,000	.....
Washington, D.C.	214,000,000	18,000	250
Total	$9,682,000,000[b]	$12,427[b]	$486[b]

[a]Based on actual project cost.
[b]Using the average costs for these cities reporting ranges.

the ammonium ion in wastewater. The regeneration brine contains the removed ammonia. The removal from and the disposal of ammonia can be accomplished by steam distillation and subsequent condensation and recovery of ammonium hydroxide. Electrolytic or chlorine oxidation of the ammonia in the brine to nitrogen gas has been demonstrated in pilot studies. Hot air stripping of ammonia from the brine, followed by acid readsorption and precipitation of ammonia salts, has also been investigated. The salts can be used as fertilizer.

Ammonia can be stripped from wastewater, although it requires from 100 to 800 cubic feet of air per gallon of water. The ammonia is usually discharged directly to the atmosphere, but this practice should be avoided in areas where the discharge could degrade the quality of the atmosphere. The process has other disadvantages: Lime or other caustic chemicals must be added to the influent before the ammonia can be stripped. Further, effectiveness of stripping decreases with decreasing atmospheric temperature.

Land Application

Often land treatment is not viewed as a treatment and discharge process. However, an underdrain or similar water removal procedure used with overland flow can achieve the effluent quality required by secondary treatment standards. This technique is presently being demonstrated in Muskegon County, Mich.

C. Storm and Combined-Sewer Control

Storm and combined-sewer overflows can be a source of significant quantities of pollutants. Demonstrated technology to control storm sewer discharges does not exist. Efforts are being made to quantify the problem and identify the effect on receiving waters.

The combined-sewer overflow problem is better quantified, and EPA research has demonstrated many types of control and treatment techniques. The techniques fall into five categories: (1) separation of sewage and storm collection systems; (2) operational control of the existing system; (3) storage and subsequent treatment; (4) dual use; and (5) direct treatment of overflows. Combinations of the techniques often result in the most cost-effective solutions, as has been demonstrated in Atlanta, Ga. and Bucyrus, Ohio.

Separation of Combined Sewers

One approach to minimizing overflows from combined sewers is to separate the systems. Complete separation is the most costly. In 1964, the cost for separating sewers in 16 cities was estimated at $9.6 billion (Table 9), for an average cost of $468 per person. The 1964 estimate for the United States was $25 to $30 billion. Today, the cost may be in excess of $50 billion.

Another approach is to partially separate the systems in a cost-effective manner. Partial separation includes separation of roof drains, area drains, foundation drains, air conditioning drains, and yard drains. This procedure would have cost $176 per person in 1964 (Table 10), or a total U. S. cost of $10.4 billion. The cost now may be in excess of $20 billion.

Control of Combined Sewers

Proper design, maintenance, and control of combined sewers (as now required for best practicable treatment) can markedly reduce the discharge of pollutants. A manual of practice prepared by the American Public Works Association for the Federal water pollution control program points to design and maintenance practices as the key to minimizing overflow pollution. Also, a study of the Hudson River concluded that proper maintenance of valves and other flow-regulating devices could substantially reduce overflows.

An even more effective control technique is regulating combined collection systems so as to utilize their capacity to the utmost. For example, Metro-Seattle uses continuous flow measurements and computerized control to divert flow to portions of the system that are under-utilized. A similar system operated by the Minneapolis-St. Paul Sanitary District (now the Metropolitan Sewer Board) reduced the quantities of overflow by 66 percent and the duration by 88 percent. The control system cost $1.75 million and had approximately the effect of a separation project costing $200 million.

Another control system which has experimentally shown promise of reducing pollution is periodic flushing of sewers during dry weather. Estimated to cost between $620 and $1,275 per acre in 1972, flushing can substantially reduce the wash out and overflow of the deposited materials from the system.

Storage and Treatment of Combined Overflows

An excellent way to eliminate or reduce combined overflows is to store and subsequently treat the overflows. This technique was successfully demonstrated in Chippewa Falls, Wis. An asphalt-paved detention basin was built to retain overflows up to a 5-year storm. The system captured 93.7 percent of the quantity of overflow, which was treated in the wastewater treatment plant during low-flow periods. The capital cost in 1972 was $6,780 per sewered acre.

Other storage devices have been tested. In Cambridge, Md., a 200,000-gallon flexible underwater container stores combined sewer over-

Table 10. ESTIMATED COSTS FOR PARTIAL SEPARATION OF STORMWATER AND SANITARY SEWERS

City	Total Project Cost	Cost/ acre	Cost/ capita
Des Moines, Iowa	$25,000,000	$7,800	$170
Elmhurst, Ill.	8,770,000	.....	237
Eugene, Ore.	3,410,000	3,100	76
Findlay, Ohio	15,106,000	.....	500
Granite City, Ill.	13,200,000	4,900	330
Hannibal, Mo.	613,000	.....	43
Kendallville, Ind.	969,000	.....	143
Lafayette, Ind.	5,024,000	.....	120
La Porte, Ind.	9,187,000	.....	437
Lathrup Village, Mich.	961,500	.....	302
Louisville, Ky.	30,538,000	.....	73
Michigan City, Ind.	3,500,000	.....	95
Minneapolis, Minn.	30,000,000	3,040	69
Mishawaka, Ind.	4,382,000	972	129
Napa, Colo.	1,549,000	640	52
Sedalia, Mo.	4,470,000	.....	213
Seattle, Wash.	69,000,000	1,880	124
Tacoma, Wash.	7,980,000	.....	53
Total	$223,651,500	$3,187[a]	$176[a]

[a]Average.

flows. This device contained 96 percent of the overflow for subsequent treatment. The capital cost was $1.85 per 1,000 gallons captured.

Dual Use

Several methods have been used to directly treat the overflow from combined sewers. In Kenosha, Wis., the existing wastewater treatment plant is operated to maximize biological adsorption in the aerator during wet-weather flows. The adsorbed organics are later biologically degraded. Prior to construction of the dual-use facility, removals of suspended solids and BOD_5 were 64 and 82 percent, respectively. Following construction, removals were 88 and 94 percent. During wet weather, the plant still removes 91 percent of suspended solids and 82.5 percent of BOD_5. This technique cost $917 per sewered acre and was $7 million cheaper than separation. Another technique is to expand the wastewater plant so that it can treat overflows, either partially or fully. The District of Columbia has designed primary sedimentation tanks to handle excessive wet-weather flows. The excessive flows will receive primary treatment and chlorination.

Treatment of Combined Overflows

Other techniques have shown capability of treating excessive wet-weather flows where land is scarce. One such technique is high-rate dual-media filtration. Experimental results showed 93 percent removal of suspended solids and 65 per-

cent removal of BOD_5 at high filter rates. In 1971, estimated capital cost for this system was approximately $23,000 per MGD of design capacity. The expected operational cost was from $90,000 per year for a 25-MGD plant to $360,000 for a 200-MGD plant. Another technique uses a rotating fine screen. In pilot plant tests, 34 percent of suspended solids, 27 percent of COD, and 99 percent of floatable and settleable solids were removed. The estimated cost for a 25-MGD plant is 22 cents per 1,000 gallons treated. In-sewer fixed screens with screen openings ranging from one-eighth inch to 1 inch have been tested, with varying degrees of success. Chemical treatment using polyelectrolytes, lime, alum, or ferric chloride is also being investigated to help treat excessive wet-weather flows.

Another treatment technique is disinfection. Chlorine gas can be used just as it is in wastewater treatment plants. Recently, however, electrochemical cells have been used to produce hypochlorite disinfectant in isolated or unattended installations. The cell uses 1.6 kilowatt hours of electricity and 2.1 pounds of salt per pound of sodium hypochlorite produced. Large installations are expected to produce chlorine for 3 to 4 cents per pound.

D. Advanced Waste Treatment (Nutrient Removal)

The term "advanced waste treatment" is used in many different ways. In this report the term is used to describe unit processes or systems designed to prevent the discharge of pollutants or nutrients which can cause accelerated euthrophication of the receiving waters. The key nutrients are carbon, nitrogen, and phosphorus. Euthrophication may be a significant problem in certain receiving waters. Nutrient removal, however, is not required by best practicable treatment on a national basis. Advanced waste treatment (or nutrient removal) techniques are usually used in conjunction with the techniques to achieve secondary treatment. The techniques fall into four categories: (1) biological; (2) physical-chemical; (3) land application; and (4) combinations.

Biological

Biological methods to remove carbon are the same techniques discussed earlier—ponds, activated sludge, and trickling filters. When higher degrees of removal are necessary, however, longer detention periods are required or improved liquid solids techniques such as larger clarifiers or filtration must be employed.

The biological method to remove nitrogen is nitrification followed by denitrification. Both can be accomplished in a mixed suspended culture followed by clarification (similar to activated sludge) or on a fixed medium (similar to a trickling filter). The Blue Plains Plant at Washington, D. C. is currently building a 300-MGD biological nitrification and denitrification system. Separate denitrification requires an organic supplement. Methanol has been most commonly used. For successful operation, approximately 3.5 parts of methanol are required to each part of nitrate nitrogen. Both nitrification and denitrification are temperature-sensitive. At 10° C. the metabolic kinetic rates can decrease to less than 20 percent of the rates observed at 30° C. Normally, nitrogen cannot be removed by a single-stage biological process. However, in recent experiments at a pilot plant in Washington, D. C. an intermittently-pulsed aerobic and anerobic system removed up to 80 percent of the nitrogen, thus drastically reducing the methanol requirements.

Recent experiments at Washington, D. C. and other localities have shown that biological removal of phosphorus can be achieved. Less than 0.55 mg/l of phosphorus was obtained in the effluent while meeting secondary treatment requirements. The system couples conventional aeration with rapid removal of solids from the clarifier. The solids are then anaerobically digested for 6 to 20 hours; the phosphorus in the sludge is released and precipitated in the side stream. The solids are then recycled to the aeration tank. The higher concentration of phosphorus in the side stream allows lower lime dosages for precipitation than full flow treatment.

Physical-Chemical

Physical-chemical methods are probably the most widely relied on in advanced waste treatment. Carbon in large complex molecules can be removed from wastewater by carbon adsorption. BOD_5 of 5 mg/l or less can be achieved. Gravity flow, pressurized downward flow, and pressurized upflow contact methods have been demonstrated utilizing a variety of size and gradation of media. The Piscataway, Md. plant is using carbon adsorption in a 5-MGD advanced waste treatment facility. Also, ozone oxidation of organic carbon has been shown to reduce the BOD_5 to substantially less than 5 mg/l in experiments in Washington.

The physical-chemical removal techniques for nitrogen include breakpoint chlorination, ion exchange, and ammonia stripping. Effluents containing less than 2.5 mg/l of total nitrogen have been produced with these techniques. Tests on breakpoint chlorination were conducted at Washington, and the method is being proposed for facilities in Cortland, N. Y.; Montgomery County, Md.; Gainesville, Fla.; Bucks County, Pa.; and Occoquan, Va. Ion exchange is being considered in Alexandria, Va. and Neosho, Mo. Ammonia stripping has already been used on

full-scale installations in Orange County and South Lake Tahoe, Calif.

Lime, ferric salts, alum and aluminum salts are used in the physical-chemical methods of removing phosphorus. Addition of the chemical and precipitation can be done throughout the process—in primary sedimentation, in the secondary system, or as a separate final stage (often termed tertiary treatment). Many plants around the Great Lakes are using ferric and alum salts in either primary or secondary stages to reduce phosphorus. Lime can be used in primary sedimentation for phosphorus removal, as demonstrated in pilot studies in Washington, or as separate tertiary treatment as currently employed in a 5-MGD plant in Piscataway, Md., and in South Lake Tahoe, Calif.; Colorado Springs, Colo.; Las Vegas, Nev.; Monroe County, N.Y.; and in other locations.

Land Application

Land application techniques discussed earlier can be designed and operated as advanced waste treatment systems. Nutrients are removed as the wastewater comes in contact with the soil and are then available to plant life.

E. Sludge Handling Techniques

An integral part of most wastewater treatment systems is the sludge handling facility. The removed pollutants and resulting chemical precipitant from the various unit processes must be processed to an environmentally sound condition for final disposal. There are several possible steps leading to final disposal: sludge stabilization, sludge thickening, sludge conditioning, and sludge dewatering. The goal of these processes is generally to minimize the noxious aspects of the sludge or remove the excess water to minimize the sludge volume to be disposed.

Sludge Stabilization

Before sludge can be disposed, it must first be treated to reduce adverse impact on receiving land, air, or ocean. The term "sludge stabilization" is used to describe those methods which will reduce the detrimental impact of sludge disposal, i. e., render the sludge as innocuous as practical. The following are the primary requirements for "stabilization": Removal or treatment of the highly volatile portion of the sludge so that rapid decomposition, with resultant rapid oxygen consumption and the creation of odors, does not occur; rendering of toxicants in a form which would not immediately and adversely affect the environment; achievement of a high degree of kill or inactivation of various types of pathogens.

a. Biological: (1) Anaerobic Digestion. Anaerobic digestion, a widely-employed process, involves biological decomposition of organic sludges in an environment devoid of dissolved oxygen. The bacterial growth is inhibited by the presence of oxygen in the sludge and often is sensitive to heavy metals. The optimum temperature for bacterial action is from between 85° and 95°F; below about 70°F, their activity practically ceases. Anaerobic digestion reduces the volatile matter by 40 to 60 percent. Since anaerobic digesters must be at a temperature of from 85° to 95°F, heating of digesters is necessary.

Anaerobic digesters are designed for single-stage or two-stage operation. In the two-stage system, the sludge in the first-stage unit, where most of the biological decomposition takes place, usually is continuously mixed by gas-lift circulation, pumped recirculation system, or mechanical mixers. In the second-stage unit, there is often no direct requirement for heating or mixing; thus, a quiescent condition is provided which leads to settling out of the solids and a supernatant.

In general, the digestion proceeds for about 30 to 60 days in either the single- or two-stage system. Higher-rate anaerobic digestion of primary and activated sludge has been successfully practiced, but operations must be strictly controlled. After equilibrium, the solids are allowed to settle and are periodically removed for dewatering. The supernatant is normally sent back to the biological treatment plant because it is high in BOD, fine suspended solids, and nutrients. However, there must be assurance that such practice will not degrade the final effluent. Otherwise, it should be given proper separate treatment. The resulting sludge normally is dewatered.

a. Biological: (2) Aerobic Digestion. Aerobic digesters for stabilizing sewage sludge are being used more frequently because of their ease of operation compared with that of anaerobic digesters. The process basically consists of aerating sludge in a tank that is usually uncovered and unheated. The principal operating cost is the power required for aeration. The sludge is supplied with oxygen so that dissolved oxygen exists in all portions of the basin. The aeration can be accomplished by means of compressed air and porous diffusers, surface-type mechanical aerators, or submerged turbines supplied with compressed air (or oxygen). However, with relatively thick sludges (above 2 percent solids), it is almost impossible to dissolve and distribute oxygen throughout the entire sludge mass unless some sort of mechanical device is used.

Aerobic digestion is not as sensitive to temperature as anaerobic digestion. There is no great adverse effect from temperature variations from between 50 to 105°F. Normally a 10- to 15-day retention time is sufficient to stabilize the sludge

and accomplish a reduction in volatile solids of from about 30 to 55 percent.

a. Biological: (3) Composting. (See the discussion of composting and final disposal in the section on "Land Utilization Techniques.")

b. Chemical: (1) Lime. The principal chemical process that can stabilize a sludge is the application of lime to obtain a pH of 11.5. It has been known for some time that applying lime to organic matter and raising its pH to above 11 will cause complex changes in the volatile solid matter, especially when such a lime-treated sludge is dewatered. If placed on the land, putrefaction will be suppressed for a considerable time; then, as the pH drops, gradual decomposition of the organic matter will occur with considerably reduced generation of odors. Furthermore, at a pH of 11.5, the destruction of organisms and inactivation of viruses are good.

b. Chemical: (2) Chlorination. Another chemical treatment that has been used recently to stabilize sludge and often enhance its dewatering characteristics is the addition of large dosages of chlorine. The equipment for this proprietary process consists of a pressure tank and recirculating pump (Purifax Process). The chlorine is applied to the raw sludge, which is pumped into a pressurized holding tank under about 45 psi and held there for from 10 to 15 minutes.

Experimental work indicated that dosages of 500 mg/l of chlorine added to each percent solids concentration of an organic sludge would eliminate odors; the color of the sludge changed from black to light tan. This chlorine dosage also increased the drainability of the sludge. The recycled liquor must be properly managed to prevent toxic or inhibitory effects to the rest of the plant.

c. Physical Methods. The only practical stabilization method that can be considered as being essentially physical is heat treatment. Since temperature of about 350 to 400°F can destroy pathogens and degrade a large portion of the volatile solids (see the later discussion of wet oxidation processes), the final sludge is considered stabilized and can be disposed on the land or in a landfill after dewatering.

Also, Pasteurization (150°F for about 1/2 hour) of liquid sludge has been considered in this country and is practiced at several localities in Germany. It destroys pathogens to a high degree, but does not stabilize the sludge since it does not reduce the volatile solids.

Sludge Thickening

Since sludge from the main treatment stream is removed at concentrations normally well below 5 percent solids, the bulk of the sludge is water. The removal of this water is desirable for many efficient and effective disposal schemes.

a. Gravity Thickening. Gravity thickening is the most common sludge concentration process in use at wastewater treatment plants. The sludge particles may be separated from water by maintaining quiescent conditions. Gravity thickeners usually follow gravity clarification, sometimes in the same unit, but the emphasis is on removing water from solids rather than solids from water, as in clarification. In thickening, the predominant mechanism is settling. An advantage of gravity thickening is its simplicity. However, in some cases gravity thickening does not normally produce as highly concentrated a sludge as do other thickening processes.

Normally primary sludge thickens readily, and often separate thickening beyond that in the primary process is not necessary. Secondary treatment sludge from a biological process normally exhibits poor thickening characteristics and requires separate external thickening. Common practice often employs a separate thickening process for both primary and secondary sludges.

b. Flotation. Like gravity settling, flotation has been adopted for thickening waste sludges, especially organic sludges that do not thicken easily by gravity settling, such as waste activated sludge. To accomplish good thickening and to also achieve a relatively clear underflow, the raw sludge is frequently "conditioned" with either an organic or inorganic coagulant.

Flotation is accomplished first by taking a volume of relatively clear water (usually the underflow) and pressurizing it up to 30 to 70 psi. Air is injected into the pressurized liquid so that dissolution occurs. This pressurized liquid is then released through a specially designed valve to a pressure equal to the hydrostatic head in the flotation basin and mixed with the raw sludge. The drop in pressure causes microscopic air bubbles to come out of solution and attach themselves to the sludge particles or floc; thus rapid flotation results.

c. Centrifugation. Centrifuges have been primarily used in the wastewater treatment field for sludge dewatering; however, recently one type of centrifuge, known as the disk or nozzle type, is coming into use for thickening of activated sludge. The disk (or nozzle) type centrifuge has been used for many years in the chemical process industry, but its use for sludge thickening in the field of wastewater treatment is relatively new, and only a few installations exist.

Sludge Conditioning

Sludge conditioning encompasses those pro-

cesses which involve biological, chemical, or physical treatment (or their combinations) to make the separation of water from sludge easier. Also, it should be kept in mind that certain conditioning processes accomplish more than merely increasing the dewaterability of sludge; they may also alter the sludge chemically, disinfect it, destroy odors, and may even accomplish a certain amount of destruction of the sludge mass by liquifaction or oxidation in some processes.

a. Chemical Conditioning. Chemical conditioning is a method used to break down the gelatinous nature of sewage sludges which makes it difficult to separate the water from the solids. By adding certain chemical flocculants, the "bound" water can be separated from the solids with much less effort and cost.

The inorganic chemicals used for such conditioning are alum, ferrous sulfate and ferric chloride, and lime. Alum is used primarily to agglomerate the fine floc of an activated sludge to aid in its thickening. Ferric sulfate is not used much because of the difficulty of getting it into solution in cold water. Ferrous sulfate is used usually with lime. The most widely used inorganic conditioner is a combination of ferric chloride and lime. The pH is raised to from 10.5 to 11.5, and good conditioning is obtained. The high pH causes the death of many pathogenic organisms and the inactivation of many viruses. The precipitated ferric hydroxide is aided in conditioning the sludge by the precipitation of calcium carbonate from the calcium alkalinity in the water and the CO_2, thus adding weight to aid in thickening light sludges.

A great many of the new organic polyelectrolytes, especially of the cationic type, are effective flocculants and conditioners. Their use does not add any significant quantity of solids, which can be important in economic considerations for sizing an incinerator.

Many sludges that do not dewater readily without a large amount of conditioning chemicals can be dewatered easily on vacuum filters by adding a "filter aid" such as diatomite, fly ash from coal-fired power plants, or sludge incinerator ash. The production of fly ash from coal-fired plants is tremendous. It has been estimated that if all secondary wastewater treatment plant sludges produced in 1970 were dewatered using such fly ash as an aid, it would only use up about one-third of the total fly ash production. Such fly ash consists principally of silica and alumina, with varying amounts of iron oxides and carbon.

b. Heat Conditioning. It is generally acknowledged that heat treatment of sludges, especially those containing a large percentage of organic matter, will greatly improve their dewaterability. Wastewater sludge can be classified as being to a large degree a colloidal-gel system, and heating allows entrapped water to escape the gel structure. Some have referred to this as "heat syneresis."

Basically, this process involves the heating of partially thickened sludge in a closed reactor up to a temperature of 350° to 400°F at a pressure of about 200 to 250 psi, and holding it under these conditions for about 30 minutes.

c. Freezing. A detailed study to evaluate conditioning and dewatering of sewage sludge by freezing was sponsored by EPA and carried out by the Milwaukee, Wis. Sewerage Commission. The initial conclusion was that the freeze-thaw process had technical merit. However, the final conclusion was that the total cost of the process was greater than existing chemical conditioning processes. Other than cost another disadvantage appeared to be that it was essentially a batch process.

Sludge Dewatering

All the various treatment processes to which the sludges have been subjected, such as thickening, stabilization, conditioning, etc., were directed, to a large degree, towards facilitating the removal of entrained water from the solids. This is termed "dewatering" so that the solids can be more economically and more readily disposed in an environmentally acceptable manner.

a. Sand Beds. The most common method of municipal wastewater sludge dewatering is on sand beds. Although sand beds are particularly suitable for small installations, they are used at treatment plants of all sizes and in geographical areas of widely varying climates. Many industrial sludges and water treatment plant sludges are also dewatered on sand beds. Generally, a well-designed and properly operated sand bed can produce a drier sludge than any mechanical dewatering device.

Dewatering on sand beds is by drainage and evaporation. The proportion removed by drainage may vary from 20 to 85 percent. Normally, most of the drainage is accomplished in the first two days on the bed; evaporation is the principal effect thereafter. After a few days, the sludge cake shrinks horizontally, producing cracks at the surface which expose additional sludge surface area and enhance drainage as well. The liquid draining from the sludge is often returned to the treatment plant. Though its volume is small, if the sludge being dried has been digested, for example, the drainage contains a high concentration of soluble organic matter, ammonia or nitrates, and phosphates. The sludge is removed by hand shovel or by a mechanical scraper device after one or more months of dewatering.

b. Vacuum Filtration. All types of municipal sludges —raw, digested, primary, activated, trickling filter, and mixtures—can be dewatered by vacuum filtration.

The rotary drum type of vacuum filter has been widely used for sludge dewatering. Basically, there are two types: the stainless steel coil filter and the belt filter, which uses a belt of fabric (usually synthetic) as the filtering medium.

The basic principle used by and of the wide variety of commercially available vacuum filters is suction. Mechanical equipment produces a vacuum on the inside of a drum. The vacuum draws the water from the sludge leaving a dry or dewatered sludge on the media side. The dewatered sludge is then removed for disposal.

c. Centrifugation. Again centrifugation can be and is used on a wide variety of municipal sludges. The basic principle is to separate the solids from the water by centrifugal force.

The unit generally used for wastewater sludge dewatering is the horizontal solid bowl centrifuge. It operates on a continuous basis and has produced a sludge cake of from 15 to 25 percent solids in normal operation.

Centrifuges require little space. However, in general, the solids capture is not as good as with vacuum filters unless optimum chemical conditioning is used, and then the cake invariably is not as dry. Centrifugation has been used successfully and competitively in practice in lieu of vacuum filtration.

d. Filter Press. The standard type filter press, or pressure leaf filter as it is sometimes called, has been used for many years in the chemical process industry for dewatering slurries. It consists of "leaves" covered with some type of porous fabric. These leaves or plates form a series of chambers; the sludge is retained between the fabric on both sides of the leaf. These plates are first pushed together and compressed by hydraulic or mechanical pressure exerted on the ends of the series of plates to prevent leakage. Drainage ports are provided in the plates for the liquid to escape. The pressure is imposed by pumping in the sludge which is retained between the filter fabrics. The final pressure can amount to several hundred psi, though usually for sewage sludge it is about 100 psi.

e. Belt Filters. Another type of filtering device used for dewatering sludge is the belt filter press. One form was first used in Europe and has been introduced to the U.S. market in recent years. It consists of two endless belts, normally made of finely woven stainless steel wire, traveling in the same direction but opposite to each other. Chemically conditioned sludge is fed continuously between the belts and is subjected to gradual pressure exerted by two individually adjustable rollers. The end product is a fairly dry sludge with solid concentration of approximately 15 percent.

This process is effective only when water and solid in the sludge are readily separable. Proper chemical conditioning prior to dewatering is therefore the key to the success of the belt filter press operation.

Another unique type of horizontal belt filter was developed in Europe and used for industrial type slurries. It depends on capillary suction action on the water portion of the conditioned sludge to extract the liquid from the sludge layer formed on top of a sponge-like belt. The liquid is squeezed out of the "sponge" belt, and the cake is further squeezed between steel rollers for additional dewatering. The sludge cake adheres to one of the rollers and is doctored off.

A unit that has been used fairly extensively is the so-called dual cell gravity concentrator. It has several unique features which produce dewatering of sludge through a synthetic porous fabric by the action of gravity. The first cell accomplishes the removal of the major portion of the water from a thickened sludge; then the sludge mass is carried over into a second cell where final dewatering is accomplished.

f. Screens. Specially designed self-cleaning metal screening devices are used (and are necessary) ahead of disk (or nozzle) type centrifuge thickeners for waste activated sludge.

At the Hyperion Treatment Plant in Los Angeles an unusual use is reportedly being made of fairly coarse horizontal and sloping screens, of the vibratory type, for removing the larger solids from digested sludge before it is disposed. The organic screened-out solids are macerated and returned to the main sludge stream, while the inert and hard materials are separated and hauled to a landfill.

Recently, a stationary sloping screen of an unusual design from a hydrodynamics standpoint has been introduced. The experience with it is still very limited, but it has application for non-flocculent type sludges, such as those from primary clarifiers and trickling filters, and for removing fibrous and discrete particles. The simplicity of design and low cost compared to other systems warrant its thorough testing and consideration.

Final Disposal

In some of the processes used to dispose the sludge to the land, air, or oceans, the sludge must be dewatered to a high degree; in others, it is disposed in liquid form, usually after some thickening. Some processes, such as incineration, may merely dispose the organic portion leaving the ash and the

liquid (if removed from the sludge before incineration) for further processing and/or disposal.

a. Incineration. Since the municipal wastewater solids and sludge (including grit and skimmings) that are generated have a large portion of organic matter, the burning of such sludge is a logical final disposal process. However, an ash remains for final disposal.

Whether the combustion is self-supporting depends on the calorific value of the solids and the degree of dewatering that was accomplished. The incinerators are always provided with auxiliary fuel for use when needed—such as during startups. Domestic wastewater sludge dewatered preferably to solids content greater than 30 percent will permit self-supporting combustion. Although either may be incinerated, raw sludge is preferable to digested sludge because of its greater calorific value.

Sewage sludge incineration has been practiced for many years and is becoming considered in urban areas as sludge volumes increase and as land areas for alternative operations become more scarce. Also, the development of greatly improved designs to control air pollution and possible recovery of the heat has increased the use of incineration. The incineration process must not produce objectionable smoke, odor, or other atmospheric pollutants.

Incineration achieves volume reduction and solids sterilization. The two most common types of sludge incinerators are the multiple hearth and the fluidized bed. A less common type is the flash drying and burning unit.

b. Wet Oxidation. In the wet air oxidation process, organic compounds in the sludge are chemically oxidized in the aqueous phase by dissolved oxygen in a specially designed reactor at temperatures of from about 500°F to 700°F and pressures of from 1,000 to 2,000 psi. The degree of oxidation achieved in the process can vary considerably, depending on sludge characteristics, temperature, and detention time. In practice, oxidations ranging from 70 to 80 percent in terms of decrease in oxygen demand are normally sought. Wet air oxidation of sludge produces a sterile, stable product that dewaters and filters readily. The process produces a sidestream when the oxidized sludge is thickened and dewatered, usually by settling, vacuum filtration, centrifugation, or a combination of these processes.

c. Land Spreading of Sludge. (See the discussion in the section on "Land Utilization Techniques.")

d. Landfill of Sludge. (See the discussion in the section on "Land Utilization Techniques.")

e. Landfill of Incinerator Ash. (See the discussion in the section on "Land Utilization Techniques.")

f. Pyrolysis of Sludge. Pyrolysis is a process involving the heating of organic matter in the absence of oxygen. The term "destructive distillation" is used when wood is subjected to this treatment to produce methanol. Depending on the nature of the organic matter, the decomposition of sludge by pyrolysis at temperatures varying from 900°F to 1,700°F produces compounds such as char, tars, various liquids, and gases such as hydrogen, carbon monoxide and dioxide, methane, and ethane.

g. Composting and Final Disposal. (See the discussion in the section on "Land Utilization Techniques.")

h. Reuse of Treatment Plant Wastes. (See the discussion in the section on "Reuse Techniques.")

CHAPTER V: REUSE TECHNIQUES

Reuse and by-product recovery is one of the major techniques for handling wastewater. Uniform criteria for best practicable treatment cannot be set for reuse purposes, since some industrial reuse needs such as cooling and quenching require minimum treatment of domestic wastewater; in other cases, water of drinking quality or better must be achieved.

The reuse criteria for best practicable treatment are set according to the medium (land or surface waters) into which reuse water is ultimately discharged and reflect two considerations: (1) as a minimum, no greater pollutional effect should result than if treatment and discharge or land application criteria were employed. This is to ensure equity among municipal works and prevent degradation of the receiving waters through the indirect discharge of untreated domestic waste; (2) as a maximum, as few additional restrictions as possible should be imposed. This is to carry out the purpose stated in the Act to encourage wastewater reuse, particularly when such facilities will produce revenue.

For the above reasons, the reuse criteria for best practicable treatment require that the quantity of pollutants discharged from a reuse project,

attributable directly to the publicly-owned treatment works, meet the minimum criteria for non-reuse techniques.

A. Reuse of Wastewater

Reuse opportunities from wastewater treatment plants do not only include reuse of the effluent, although this technique is still the most important. Use of methane gas from anaerobic digestion, recovery of coagulant in systems employing lime precipitation, and regeneration of activated carbon are also possible.

The effluent quality required for reuse may vary as discussed earlier. In many cases, reuse may require additional treatment beyond nutrient removal. Often the problem is high dissolved-solids concentration, for which several methods have been proposed. The most advanced technology of dissolved-solids removal is reverse osmosis. Distillation, ion exchange, and freezing techniques are still in the research or small-scale pilot stage.

A major steel company in Baltimore, Md. obtains sewage which does not receive secondary treatment. The industry treats to its needs. Other systems, such as one being planned at the Central Costa Sanitary District, Calif., require advanced waste treatment prior to industrial reuse. The Central Costa facility is expected to be revenue-producing.

Recharging ground water, directly or indirectly, is also a potential reuse and is being practiced with increasing frequency in the arid Southwest. Also, in the East, Long Island, N. Y. is recognizing the need for ground water recharge and is planning a demonstration study. The prevention of salt water intrusion is also an excellent reuse opportunity. Direct reuse for drinking water is being practiced in Windhok, South Africa, but not in this country.

Another wastewater reuse is in development of arid land. Examples include grassland or golf courses watered with treated effluent, development of forest land (being researched at the University of Pennsylvania), and a recreation facility developed by Los Angeles County in Antelope Valley, Calif. New land application techniques are expected to provide conditions for producing sod, Christmas trees, hay, or even beef cattle. The treated effluent from the South Lake Tahoe, Calif. plant is pumped to a reservoir for eventual use in irrigation. Highly-treated wastewater from the proposed Upper Occoquan, Va. plant will be discharged to a reservoir used for water supply.

In a land application system the water recovered and used for subsequent irrigation is considered a reuse technique. That portion must comply with the irrigation requirements. Only the water remaining as permanent ground water must comply with the standards for land application.

Revenue-producing facilities are being considered with increasing frequency. A plant in the Central Contra Costa Sanitary District, Calif., is in the early design stage. It is expected to sell highly-treated effluent to industries, thereby saving major development of new water supplies.

B. Reuse of Treatment-Plant Wastes

Reuse of treatment-plant wastes such as sludges, methane gas, and waste-activated carbon is also possible. For several decades, methane gas from anaerobic digestion of a sludge has been used for fuel, electrical power generation, and heat.

Sludge can also be reused. The sale of dried sludge as a soil-builder, a unique operation in Milwaukee, Wis., has been revenue-producing. Another technique, demonstrated in pilot studies in Washington, D. C. and in full-scale operations at Piscataway, Md. and South Lake Tahoe, Calif., recovers coagulant from a lime precipitation process. The organic sludge is incinerated; the calcium carbonate that results from lime precipitation is calcined back to lime for subsequent reuse. South Lake Tahoe also has facilities to reactivate the activated carbon spent in wastewater treatment.

Other sludge-reuse techniques are also being investigated. Acid treatment of alum sludges to recover alum is actually being used in Japan. Hydrolysis of organic sludges, which employs sulfur dioxide, heat and pressure, shows potential in producing animal feed. After the hydrolysis, evaporation concentrates digestible organics valued at 2 to 5 cents per pound. Organic and chemical sludges can also be used to condition barren soil and improve cashcrop potential.

C. Integrated Reuse Facilities

Reuse techniques benefit from total area planning and increasing utilization of integrated facilities. One potential integrated facility is the proposed Delaware Reclamation Project, where wastewater treatment sludges, municipal refuse, and garbage would be composted, separated, and heat-treated. At another proposed facility in Montgomery County, Md., organic sludges would be pretreated and used as a supplemental fuel source in thermoelectric power production. The effluent could also be used to supplement cooling water. Other integrated concepts which have been widely used are incorporation of septic-tank treatment capabilities in a plant and the use of joint municipal and industrial treatment facilities.

APPENDIX A—BIBLIOGRAPHY

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APPENDIX B—COST-EFFECTIVENESS ANALYSIS GUIDELINES (40 CFR 35 - APPENDIX A)

federal register

Title 40—Protection of the Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—GRANTS

PART 35—STATE AND LOCAL ASSISTANCE

Appendix A—Cost-Effectiveness Analysis

On July 3, 1973, notice was published in the FEDERAL REGISTER that the Environmental Protection Agency was proposing guidelines on cost-effectiveness analysis pursuant to section 212(2)(c) of the Federal Water Pollution Act Amendments of 1972 (the Act) to be published as appendix A to 40 CFR part 35.

Written comments on the proposed rulemaking were invited and received from interested parties. The Environmental Protection Agency has carefully considered all comments received. No changes were made in the guidelines as earlier proposed. All written comments are on file with the agency.

Effective date.—These regulations shall become effective October 10, 1973.

Dated September 4, 1973.

JOHN QUARLES,
Acting Administrator.

APPENDIX A

COST EFFECTIVENESS ANALYSIS GUIDELINES

a. *Purpose.*—These guidelines provide a basic methodology for determining the most cost-effective waste treatment management system or the most cost-effective component part of any waste treatment management system.

b. *Authority.*—The guidelines contained herein are provided pursuant to section 212(2)(C) of the Federal Water Pollution Control Act Amendments of 1972 (the Act).

c. *Applicability.*—These guidelines apply to the development of plans for and the selection of component parts of a waste treatment management system for which a Federal grant is awarded under 40 CFR, Part 35.

d. *Definitions.*—Definitions of terms used in these guidelines are as follows:

(1) *Waste treatment management system.*—A system used to restore the integrity of the Nation's waters. Waste treatment management system is used synonymously with "treatment works" as defined in 40 CFR, Part 35.905-15.

(2) *Cost-effectiveness analysis.*—An analysis performed to determine which waste treatment management system or component part thereof will result in the minimum total resources costs over time to meet the Federal, State or local requirements.

(3) *Planning period.*—The period over which a waste treatment management system is evaluated for cost-effectiveness. The planning period commences with the initial operation of the system.

(4) *Service life.*—The period of time during which a component of a waste treatment management system will be capable of performing a function.

(5) *Useful life.*—The period of time during which a component of a waste treatment management system will be required to perform a function which is necessary to the system's operation.

e. *Identification, selection and screening of alternatives.*—(1) *Identification of alternatives.*—All feasible alternative waste management systems shall be initially identified. These alternatives should include systems discharging to receiving waters, systems using land or subsurface disposal techniques, and systems employing the reuse of wastewater. In identifying alternatives, the possibility of staged development of the system shall be considered.

(2) *Screening of alternatives.*—The identified alternatives shall be systematically screened to define those capable of meeting the applicable Federal, State, and local criteria.

(3) *Selection of alternatives.*—The screened alternatives shall be initially analyzed to determine which systems have cost-effective potential and which should be fully evaluated according to the cost-effectiveness analysis procedures established in these guidelines.

(4) *Extent of effort.*—The extent of effort and the level of sophistication used in the cost-effectiveness analysis should reflect the size and importance of the project.

f. *Cost-Effective analysis procedures.*—(1) *Method of Analysis.*—The resources costs shall be evaluated through the use of opportunity costs. For those resources that can be expressed in monetary terms, the interest (discount) rate established in section (f)(3) will be used. Monetary costs shall be calculated in terms of present worth values or equivalent annual values over the planning period as defined in section (f)(2). Nonmonetary factors (e.g., social and environmental) shall be accounted for descriptively in the analysis in order to determine their significance and impact.

The most cost-effective alternative shall be the waste treatment management system determined from the analysis to have the lowest present worth and/or equivalent annual value without overriding adverse nonmonetary costs and to realize at least identical minimum benefits in terms of applicable Federal, State, and local standards for effluent quality, water quality, water reuse and/or land and subsurface disposal.

(2) *Planning period.*—The planning period for the cost-effectiveness analysis shall be 20 years.

(3) *Elements of cost.*—The costs to be considered shall include the total values of the resources attributable to the waste treatment management system or to one of its component parts. To determine these values, all monies necessary for capital construction costs and operation and maintenance costs shall be identified.

Capital construction costs used in a cost-effectiveness analysis shall include all contractors' costs of construction including overhead and profit; costs of land, relocation, and right-of-way and easement acquisition; design engineering, field exploration, and engineering services during construction; administrative and legal services including costs of bond sales; startup costs such as operator training; and interest during construction. Contingency allowances consistent with the level of complexity and detail of the cost estimates shall be included.

Annual costs for operation and maintenance (including routine replacement of equipment and equipment parts) shall be included in the cost-effectiveness analysis. These costs shall be adequate to ensure effective and dependable operation during the planning period for the system. Annual costs shall be divided between fixed annual costs and costs which would be dependent on the annual quantity of wastewater collected and treated.

(4) *Prices.*—The various components of cost shall be calculated on the basis of market prices prevailing at the time of the cost-effectiveness analysis. Inflation of wages and prices shall not be considered in the analysis. The implied assumption is that all prices involved will tend to change over time by approximately the same percentage. Thus, the results of the cost effectiveness analysis will not be affected by changes in the general level of prices.

Exceptions to the foregoing can be made if their is justification for expecting significant changes in the relative prices of certain items during the planning period. If such cases are identified, the expected change in these prices should be made to reflect their future relative deviation from the general price level.

(5) *Interest (discount) rate.*—A rate of 7 percent per year will be used for the cost-effectiveness analysis until the promulgation of the Water Resources Council's "Proposed Principles and Standards for Planning Water and Related Land Resources." After promulgation of the above regulation, the rate established for water resource projects shall be used for the cost-effectiveness analysis.

(6) *Interest during construction.*—In cases where capital expenditures can be expected to be fairly uniform during the construction period, interest during construction may be calculated as $I \times \frac{1}{2} P \times C$ where:

I = the interest (discount) rate in Section f(5).
P = the construction period in years.
C = the total capital expenditures.

In cases when expenditures will not be uniform, or when the construction period will be greater than three years, interest during construction shall be calculated on a year-by-year basis.

(7) *Service life.*—The service life of treatment works for a cost-effectiveness analysis shall be as follows:

Land	Permanent
Structures (includes plant buildings, concrete process tankage, basins, etc.; sewage collection and conveyance pipelines; lift station structures; tunnels; outfalls)	30–50 years
Process equipment (includes major process equipment such as clarifier mechanism, vacuum filters, etc.; steel process tankage and chemical storage facilities; electrical generating facilities on standby service only).	15–30 years
Auxiliary equipment (includes instruments and control facilities; sewage pumps and electric motors; mechanical equipment such as compressors, aeration systems, centrifuges, chlorinators, etc.; electrical generating facilities on regular service).	10–15 years

Other service life periods will be acceptable when sufficient justification can be provided.

Where a system or a component is for interim service and the anticipated useful life is less than the service life, the useful life shall be substituted for the service life of the facility in the analysis.

(8) *Salvage value.*—Land for treatment works, including land used as part of the treatment process or for ultimate disposal of residues, shall be assumed to have a salvage value at the end of the planning period equal to its prevailing market value at the time of the analysis. Right-of-way easements shall be considered to have a salvage value not greater than the prevailing market value at the time of the analysis.

Structures will be assumed to have a salvage value if there is a use for such structures at the end of the planning period. In this case, salvage value shall be estimated using straightline depreciation during the service life of the treatment works.

For phased additions of process equipment and auxiliary equipment, salvage value at the end of the planning period may be estimated under the same conditions and on the same basis as described above for structures.

When the anticipated useful life of a facility is less than 20 years (for analysis of interim facilities), salvage value can be claimed for equipment where it can be clearly demonstrated that a specific market or reuse opportunity will exist.

[FR Doc.73-19104 Filed 9-7-73;8:45 am]

APPENDIX C—SECONDARY TREATMENT INFORMATION (40 CFR 133)

federal register

FRIDAY, AUGUST 17, 1973
WASHINGTON, D.C.
Volume 38 ■ Number 159

PART II

ENVIRONMENTAL PROTECTION AGENCY

■

WATER PROGRAMS

Secondary Treatment Information

No. 159—Pt. II——1

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 133—SECONDARY TREATMENT INFORMATION

On April 30, 1973, notice was published in the FEDERAL REGISTER that the Environmental Protection Agency was proposing information on secondary treatment pursuant to section 304(d)(1) of the Federal Water Pollution Control Act Amendments of 1972 (the Act). Reference should be made to the preamble of the proposed rulemaking for a description of the purposes and intended use of the regulation.

Written comments on the proposed rulemaking were invited and received from interested parties. The Environmental Protection Agency has carefully considered all comments received. All written comments are on file with the Agency.

The regulation has been reorganized and rewritten to improve clarity. Major changes that were made as a result of comments received are summarized below:

(a) The terms "1-week" and "1-month" as used in § 133.102 (a) and (b) of the proposed rulemaking have been changed to 7 consecutive days and 30 consecutive days respectively (See § 133.102 (a), (b), and (c)).

(b) Some comments indicated that the proposed rulemaking appeared to require 85 percent removal of biochemical oxygen demand and suspended solids only in cases when a treatment works would treat a substantial portion of extremely high strength industrial waste (See § 133.102(g) of the proposed rulemaking). The intent was that in no case should the percentage removal of biochemical oxygen demand and suspended solids in a 30 day period be less than 85 percent. This has been clarified in the regulation. In addition, it has been expressed as percent remaining rather than percent removal calculated using the arithmetic means of the values for influent and effluent samples collected in a 30 day period (See § 133.102(a) and (b)).

(c) Comments were made as to the difficulty of achieving 85 percent removal of biochemical oxygen demand and suspended solids during wet weather for treatment works receiving flows from combined sewer systems. Recognizing this, a paragraph was added which will allow waiver or adjustment of that requirement on a case-by-case basis (See § 133.103(a)).

(d) The definition of a 24-hour composite sample (See § 133.102(c) of the proposed rulemaking) was deleted from the regulation. The sampling requirements for publicly owned treatment works will be established in guidelines issued pursuant to sections 304(g) and 402 of the Act.

(e) In § 133.103 of the proposed rulemaking, it was recognized that secondary treatment processes are subject to upsets over which little or no control may be exercised. This provision has been deleted. It is no longer considered necessary in this regulation since procedures for notice and review of upset incidents will be included in discharge permits issued pursuant to section 402 of the Act.

(f) Paragraph (f) of § 133.102 of the proposed rulemaking, which relates to treatment works which receive substantial portions of high strength industrial wastes, has been rewritten for clarity. In addition, a provision has been added which limits the use of the upwards adjustment provision to only those cases in which the flow or loading from an industry category exceeds 10 percent of the design flow or loading of the treatment works. This intended to reduce or eliminate the administrative burden which would be involved in making insignificant adjustments in the biochemical oxygen demand and suspended solids criteria (See § 133.103(b)).

The major comments for which changes were not made are discussed below:

(a) Comments were received which recommended that the regulation be written to allow effluent limitations to be based on the treatment necessary to meet water quality standards. No change has been made in the regulations because the Act and its legislative history clearly show that the regulation is to be based on the capabilities of secondary treatment technology and not ambient water quality effects.

(b) A number of comments were received which pointed out that waste stabilization ponds alone are not generally capable of achieving the proposed effluent quality in terms of suspended solids and fecal coliform bacteria. A few commenters expressed the opposite view. The Agency is of the opinion that with proper design (including solids separation processes and disinfection in some cases) and operation, the level of effluent quality specified can be achieved with waste stabilization ponds. A technical bulletin will be published in the near future which will provide guidance on the design and operation of waste stabilization ponds.

(c) Disinfection must be employed in order to achieve the fecal coliform bacteria levels specified. A few commenters argued that disinfectant is not a secondary treatment process and therefore the fecal coliform bacteria requirements should be deleted. No changes were made because disinfection is considered by the Agency to be an important element of secondary treatment which is necessary for protection of public health (See § 133.102(c)).

Effective date. These regulations shall become effective on August 17, 1973.

JOHN QUARLES,
Acting Administrator

AUGUST 14, 1973.

Chapter I of title 40 of the Code of Federal Regulations is amended by adding a new Part 133 as follows:

Sec.
133.100 Purpose.
133.101 Authority.
133.102 Secondary treatment.
133.103 Special considerations.
133.104 Sampling and test procedures.

AUTHORITY: Secs. 304(d)(1), 301(b)(1)(B), Federal Water Pollution Control Act Amendments, 1972, P.L. 92-500.

§ 133.100 Purpose.

This part provides information on the level of effluent quality attainable through the application of secondary treatment.

§ 133.101 Authority.

The information contained in this Part is provided pursuant to sections 304(d)(1) and 301(b)(1)(B) of the Federal Water Pollution Control Act Amendments of 1972, PL 92-500 (the Act).

§ 133.102 Secondary treatment.

The following paragraphs describe the minimum level of effluent quality attainable by secondary treatment in terms of the parameters biochemical oxygen demand, suspended solids, fecal coliform bacteria and pH. All requirements for each parameter shall be achieved except as provided for in § 133.103.

(a) *Biochemical oxygen demand (5-day).* (1) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 30 milligrams per liter.

(2) The arithmetic mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 45 milligrams per liter.

(3) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period (85 percent removal).

(b) *Suspended solids.* (1) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 30 milligrams per liter.

(2) The arithmetic mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 45 milligrams per liter.

(3) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period (85 percent removal).

(c) *Fecal coliform bacteria.* (1) The geometric mean of the value for effluent samples collected in a period of 30 consecutive days shall not exceed 200 per 100 milliliters.

(2) The geometric mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 400 per 100 milliliters.

(d) *pH*. The effluent values for pH shall remain within the limits of 6.0 to 9.0.

§ 133.103 Special considerations.

(a) *Combined sewers*. Secondary treatment may not be capable of meeting the percentage removal requirements of paragraphs (a)(3) and (b)(3) of § 133.102 during wet weather in treatment works which receive flows from combined sewers (sewers which are designed to transport both storm water and sanitary sewage). For such treatment works, the decision must be made on a case-by-case basis as to whether any attainable percentage removal level can be defined, and if so, what that level should be.

(b) *Industrial wastes*. For certain industrial categories, the discharge to navigable waters of biochemical oxygen demand and suspended solids permitted under sections 301(b)(1)(A)(i) or 306 of the Act may be less stringent than the values given in paragraphs (a)(1) and (b)(1) of § 133.102. In cases when wastes would be introduced from such an industrial category into a publicly owned treatment works, the values for biochemical oxygen demand and suspended solids in paragraphs (a)(1) and (b)(1) of § 133.102 may be adjusted upwards provided that: (1) the permitted discharge of such pollutants, attributable to the industrial category, would not be greater than that which would be permitted under sections 301(b)(1)(a)(i) or 306 of the Act if such industrial category were to discharge directly into the navigable waters, and (2) the flow or loading of such pollutants introduced by the industrial category exceeds 10 percent of the design flow or loading of the publicly owned treatment works. When such an adjustment is made, the values for biochemical oxygen demand or suspended solids in paragraphs (a)(2) and (b)(2) of § 133.102 should be adjusted proportionally.

§ 133.104 Sampling and test procedures.

(a) Sampling and test procedures for pollutants listed in § 133.102 shall be in accordance with guidelines promulgated by the Administrator pursuant to sections 304(g) and 402 of the Act.

(b) Chemical oxygen demand (COD) or total organic carbon (TOC) may be substituted for biochemical oxygen demand (BOD) when a long-term BOD: COD or BOD:TOC correlation has been demonstrated.

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APPENDIX D

GROUND WATER REQUIREMENTS

Water Treatment Requirements*

1. General Requirements

The water quality requirements of the EPA Drinking Water Standards are minimum requirements, and good quality water should have physical and chemical characteristics considerably better than the limiting values established in the EPA Drinking Water Standards (Sections 4.2, 5.1, 5.2, 6.1, and 6.2). For example, water with turbidity of 5 units and a color of 15 units may be acceptable, but in a coagulated, filtered water such values could indicate serious malfunctioning of the purification process. (The EPA Drinking Water Standards are being revised currently, and will contain a recommendation that the turbidity standard be reduced to 1 turbidity unit. This and other revisions of the Drinking Water Standards, proposed at the time of this printing, are shown on the following pages.) Similarly, increased concentrations of copper and iron could indicate a corrosiveness that would be objectionable to consumers, even though the concentrations of the metals did not exceed recommended limits. In well water an increase in chlorides over the normal amount found in ground waters in the area may be the first indication of pollution.

The type of treatment required depends on the characteristics of the watershed, the raw water quality, and the desired finished water quality. If pollution of the source water is increasing, plant facilities, which were adequate for treatment of a nonpolluted water, may become inadequate. The production of water that is free from pathogenic organisms, aesthetically satisfactory to the senses, and reasonably acceptable chemically becomes increasingly difficult when the raw water has a high and varying chlorine demand, contains large numbers of coliform bacteria, or contains high concentrations of dissolved solids, toxic substances, or taste and odor producing substances.

When evaluating the ability of a water supply system to constantly produce a safe and satisfactory water, these factors should be considered:

(a) the quality of water produced at times of unusual stress, such as during heavy run-offs, periods of drought, or periods of excessive demand as shown in the records;

(b) the quality of the raw and finished waters, as determined by laboratory data and sanitary surveys, and any trends in improvement or deterioration;

(c) the purification processes, including the facilities used to apply disinfectants at various locations in the treatment process, and their capacities compared with the capacities considered necessary to meet maximum anticipated requirements;

(d) the treatment processes used and their reliability in changing raw water characteristics to produce a finished water that continuously meets the PHS Drinking Water Standards;

(e) the minimum residual chlorine concentration in the plant effluent water, when chlorine is used, together with the time that this or greater chlorine levels were maintained;

(f) the qualifications of the operators and laboratory personnel, as indicated by appropriate training, or certification, or both; and

*"Manual For Evaluating Public Drinking Water Supplies" U.S. Environmental Protection Agency, 1971, pp. 4-12; updated with Proposed Primary Drinking Water Regulations, June 1975.

(g) the laboratory facilities and analytical procedures, frequency and extent of their use, and application of the data to operational control.

2. Extent of Treatment

The Public Health Service recommends that all municipal water supplies, whether they be ground water or surface water, receive treatment by disinfection regardless of the quality of the water. The benefits from the added protection provided by disinfection far outweigh the increased cost and the added maintenance incurred by the water utility. When coliform density is used as one criterion for judging treatment requirements, raw waters can be divided into three groups: clean, clear, and polluted waters. The coliform densities of the raw waters can be expressed in terms of the most probable number (MPN) from the multiple-tube fermentation technique, or actual coliform counts determined by the membrane filter (MF) technique.

The requirements are given for three groups of water: those usable without treatment, those needing disinfection only, and those needing complete treatment. The quality requirements listed below are the proposed EPA primary drinking water standards*, that are proposed as revisions to the current PHS Drinking Water Standards. They differ from the current PHS Standards in that some standards have been added, some have been deleted, and others modified.**

Group I. Requirements for Water Usable Without Treatment

A. *Bacteriological Quality:* The coliform standard remains the same as the PHS Drinking Water Standards, 1962, plus the inclusion of a standard plate count limit of 500 organisms per ml.

B. *Physical Quality:* should meet the following standards.

Turbidity	1 turbidity unit (up to 5 TU may be allowed in some cases)

*Proposed Interim Primary Drinking Water Regulation, March 14, 1975

**The EPA is also considering secondary drinking water regulations pertaining to color, taste and odor, chloride, copper, foaming agents, iron, manganese, sulfate and zinc. Ground water requirements for land application systems should consider these parameters in terms of aesthetic acceptability of existing and potential drinking water supplies and the cost-effectiveness of control by standard water treatment practice.

C. Chemical Quality: chemical concentrations should not exceed the following:

Substance	Maximum Allowable Limits concentration mg/liter
Arsenic (As)	0.05
Barium (Ba)	1
Cadmium (Cd)	0.010
Chromium (Cr)	0.05
Cyanide (CN)	0.2
Flouride (F) [a]	
up to 53.7°F	2.4
53.8-58.3	2.2
58.4-63.8	2.0
63.9-70.6	1.8
70.7-79.2	1.6
79.3-90.5	1.4
Lead (Pb)	0.05
Mercury (Hg)	0.002
Nitrate Nitrogen	10
Organics-Carbon Absorbable CCE	0.7
Selenium (Se)	0.01
Silver (Ag)	0.05

[a] Annual average of maximum daily air temperature.

Substances not included in the above table that may have deleterious physiological effect or that may be excessively corrosive to the water supply system should not be permitted in the raw water supply.

D. Radioactivity: should comply with the following limits:

RADIUM 226, RADIUM 228, and GROSS ALPHA PARTICLE RADIOACTIVITY

Combined Radium 226 and Radium 228 - 5pCi/l

Gross Alpha Particle Activity - 15 pCi/l

BETA PARTICLE and PHOTON RADIOACTIVITY from MAN-MADE RADIONUCLIDES

The average annual concentration of beta particle and photon radioactivity from man-made radionuclides shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem, assuming a 2 liter per day drinking water intake.

E. *Pesticides:* should not exceed the following limits:

Pesticide	Maximum permissible concentration, mg/l
Chlordane	0.003
Endrin	0.0002
Heptachlor	0.0001
Heptachlor epoxide	0.0001
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2, 4-D	0.1
2, 4, 5-TP	0.01

Group II. Requirements for Water Needing Disinfection Only

A. *Physical, Chemical, Radioactivity, and Pesticide Requirements:* the requirements as shown for untreated raw ground water (Groups I.B, I.C, I.D, and I.E) should be met. If the water does not consistently meet all these requirements, consideration should be given to providing additional treatment during periodic decreases in quality that result from high turbidity, tastes, etc.

B. *Bacteriological Quality:*

1. Fecal Coliform Density: If fecal coliform density is measured, the total coliform density discussed below may be exceeded, but fecal coliform density should not, in any case, exceed 20 per 100 milliliters as measured by a monthly arithmetic mean. When the fecal coilform vs. total coliform criterion is used for Group II water, the fecal coliform count should never exceed the 20 per 100 milliliters monthly arithmetic mean. This fecal coliform standard only applies when it is being measured on a regular basis.
2. Total Coliform Density: Less than 100 per 100 milliliters as measured by a monthly arithmetic mean.

Group III. Requirements for Water Needing Treatment by Complete Conventional Means Including Coagulation, Sedimentation, Rapid Granular Filtration, and Disinfection (Pre and Post)

C. *Bacteriological Quality:*

1. Fecal Coliform Density: If fecal coliform density is measured, the total coliform density discussed below may be exceeded, but fecal coliform should not exceed 2,000 per 100 milliliters as measured by a monthly geometric mean.

2. Total Coliform Density: Less than 20,000 per 100 milliliters as measured by a monthly geometric mean.

   The same rationale applies here as in the Group II waters concerning the use of the fecal coliform vs. total coliform criterion. In no case should the fecal coliform count exceed the 2,000 per 100 milliliters monthly geometric mean.

   The arithmetic mean is used with the Group II waters because the bacteriological data from these waters will be of lesser magnitude than that from the Group III waters; this difference in magnitude between the monthly means of the Group II and Group III waters is best reflected by the arithmetic and geometric means, respectively.

   These bacteriological limits may possibly be exceeded if treatment (in addition to coagulation, sedimentation, rapid granular filtration, and disinfection) is provided and is shown to be doing a satisfactory job of providing health protection.

B. *Physical Quality:* Elements of color, odor, and turbidity contribute significantly to the treatability and potability of the water.

1. Color: A limit of 75 color units should not be exceeded. This limit applies only to nonindustrial sources; industrial concentrations of color should be handled on a case-by-case basis and should not exceed levels that are treatable by complete conventional means.
2. Odor: A limit of 5 threshold numbers should not be exceeded.
3. Turbidity: The limits for turbidity are variable. Factors of nature, size, and electrical charge for the different particles causing turbidity require a variable limit. Turbidity should remain within a range that is readily treatable by complete conventional means. It should not overload the water treatment works, and it should not change rapidly either in nature or in concentration when such rapid shifts would upset normal treatment operations.

C. *Chemical Quality*: Since there is little reduction in chemical constituents with complete conventional treatment, raw water should meet the limits given for Group I.C.

D. *Radioactivity*: Should comply with Certification Limits given in Group I.D.

E. *Pesticides*: Should comply with requirements for pesticides as shown for untreated raw ground water in Group I.E.

Infectious material, the increasing diversity of chemical pollutants found in Group III raw waters, and the many different situations encountered in regional and local problems make it impractical to prescribe a limited selection of facilities and processes that can effectively handle all problems presented by raw water and its sources. Future improvements in treatment technology cannot be reasonably assisted or regulated by requiring the fixed process steps considered good for today's technology. Table 1 describes some factors that increase the difficulty in securing disinfection, e.g., adequate disinfection with halogens depends on temperature, pH, contact time, and concentration of disinfectant.

Types of disinfection other than chlorination must be demonstrated to function effectively in all compositions of water likely to be encountered from the source used. If a distribution system is of any considerably length, the disinfection method should provide a residual protection that can be easily measured.

Table 1. CONDITIONS CREATING DIFFICULTIES AT THE WATER PLANT AND IN THE WATER MAINS		
Bacterial and biological conditions	Chemical conditions	Physical and operational conditions
Increasing numbers of coliforms Biological pollution, i.e., algal or fungal metabolic products that effect chlorine demand Filter clogging organisms that effect chlorine demand	Ammonia nitrogen Toxic materials or taste and odor requiring removal Color or organic dispersing agents (anticoagulants), ligni compounds Chlorine demand Iron and manganese High organic content High or organic content High or fluctuating pH	Low temperature Extended distribution systems Highly variable water quality Rapid variation in flow and turbidity of surface water resource Tidal effects

Where water sources show continuing quality deterioration or the quality of water available is not adequate for future demand, the water purveyor should be examining alternate or auxiliary sources of supply and should have positive plans to procure adequate facilities and sources.